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ESSAYS
ON
UNEXPLAINED PHENOMENA:
CONTAINING
NEW VIEWS
REGARDING THE
CAUSE OF CENTRIFUGAL FORCE IN PLANETARY MOTION;
THE RADIATION OF CALORIC;
AND
THE CENTRAL HEAT OF THE EARTH;

WITH
REFUTATIONS OF MANY EXISTING OPINIONS
ON THESE SUBJECTS.

BY
GRAHAM HUTCHISON,
AUTHOR OF A TREATISE ON THE CAUSES AND PRINCIPLES OF METEOROLOGICAL
PHENOMENA; AND OF ESSAYS ON MARSH FEVERS, AND ON
OWEN'S SYSTEM OF EQUALITY.

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PREFACE.

THE Unexplained Phenomena treated of in this volume, are partly Astronomical, partly Meteorological, and partly Geological. And though, judging from the manner in which the subjects are divided, there may appear, at first sight, to be three distinct and unconnected treatises; on perusal, it will be perceived, that they are so far related, that the facts, arguments, and explanations, contained in the second treatise, tend to illustrate and confirm the opinions advanced in the first; and the new views contained in the third, are principally intended to obviate objections which might otherwise have been urged, in refutation of the opinions advanced in the two preceding treatises.

The fundamental principle revealed, and applied to the explanation of the various phenomena treated of in the following pages, is, that the repellent force subsisting between particles of caloric, and also between the homogeneous particles of other imponderable bodies, instead of being restricted in the sphere of its operation, to insensible, or very limited distances, as has been hitherto supposed, extends to all distances. And the law by which its influence is exerted, is the same as that which has hitherto been exclusively applied to attraction subsisting between ponderable bodies, viz. that the repellent force subsisting between materials that repel each other, increases directly as the mass or amount of matter which repels, and inversely as the square of the distance at which it acts.

All bodies that we can subject to examination, are composed of ponderable and imponderable materials. And if these materials, in conformity with the above-stated law, be at all times, and all distances, exerting the same mutual attractive and repulsive relations towards each other; it follows, that the gravitating tendency of all substances around us towards the earth's centre, and mutually subsisting between distant planetary orbs, is the result, not exclusively of attraction, as has been hitherto imagined, but of the preponderance of the attractive over the repulsive forces, which all aggregate bodies, composed of ponderable and imponderable materials, are constantly and simultaneously exerting towards each other.

The following views, relative to the Nature and Cause of Centrifugal Force, and Calorific Radiation, consist but of an extension of the principle above stated, applied to the explanation of what has been left unexplained in these departments of physical science. And it so happens, that the phenomena presented to observation, strikingly harmonize with the fundamental principle from which the explanatory views are deduced. Besides, a variety of phenomena connected with radiation, (such as the Difference in the Heating Power of the Sun's Rays in different latitudes, treated of in Sections XXVIII., XXIX., XXX., and XXXI., and likewise those treated of in Section XXXIV.,) though diametrically opposed to the present notions on that subject, and accordingly hitherto inexplicable, admit of a simple and satisfactory explanation, by means of the hypothesis we have advanced. They are, in reality, obvious and necessary results, arising out of the fundamental principles unfolded in the subsequent pages; and, consequently, afford strong confirmation of their truth.

Since the law of gravitation was revealed by Newton, astronomers appear to have thought that nothing farther regarding the primary cause of planetary motion remained to be discovered. The orbitual movement of planetary bodies requiring the assistance of another force besides attraction, it seems just to have been taken for granted, without examination, that a centrifugal velocity had been originally communicated to planetary bodies, without the agency of any material or physical cause; and that, too, in the exact proportion required to balance their several exceedingly diversified centripetal tendencies. Subsequent astronomical researches have, accordingly, been chiefly directed to explain, in conformity with the law of gravitation, small secular and periodic irregularities in the movements of planetary bodies, which rotation, and the consequent departure of their configuration from perfect sphericity, together with their mutual perturbations, produced.

I know not where, or by whom, the opinion at present commonly received regarding the cause of centrifugal force in planetary motion, was first promulgated. In the absence, however, of information on this point, it may be conjectured, that it might originate in some such way as the following.

After the discovery of the law of gravitation, it would be apparent, that to prevent the mutual approximation of planetary bodies, and to account for their continuing permanently to revolve in the same orbits, the aid of some other force besides that of mutual attraction, was requisite. In the absence of other guides to direct us in the investigation of the cause of any phenomenon, we are naturally led to consider what would produce the effect. Reasoning upon this principle, it would immediately be perceived, that if the celestial spaces in which planets revolve in their orbits be entirely void of matter, an impulse originally communicated to planetary bodies at, or nearly at, right angles to the centripetal force, and in the proportion required to balance their respective centripetal tendencies, would cause them permanently to revolve in the same orbits; and, consequently, would account for the phenomenon of orbitual revolution. Such is the most likely manner, in which the commonly received opinion regarding the cause of centrifugal force, may have originated. And though, as we have endeavoured to demonstrate, it was merely an arbitrary, and very improbable assumption, resting on no evidence whatever, and had recourse to solely on the ground of convenience; yet, having no opposing theory or hypothesis to contend with, and there being no other known method of accounting for the phenomenon; when once promulgated, it must soon have been universally received.

The views unfolded in the first portion of this volume, deviate from those hitherto promulgated, by showing that planetary motion, including both the centripetal and centrifugal forces, is the result of the mutual attraction subsisting between the ponderable materials contained in different celestial orbs, acting in conjunction with the mutual repulsion subsisting between the imponderable materials, concentrated by attraction within, and around, their respective surfaces. I ascribe both the centripetal and centrifugal tendencies to the agency of attractive and repulsive properties, admitted to be inherent in different kinds of materials by which we are surrounded; whereas, according to existing notions, the centripetal force only is attributed to the mutual attraction of matter, and the centrifugal tendency is supposed to exist without the agency of any material cause whatever. I believe that all the movements and arrangements of the different planetary systems of the universe, are results of the mutual action and re-action of the attractive and repulsive properties, which Providence has originally and permanently conferred upon the elementary materials of which they are severally composed. Whereas, according to existing notions, the attractive properties of matter only are instrumental towards the production of the observed effects, and the influence of the repulsive force subsisting between the particles of certain kinds of matter, is totally neglected and lost sight of. Our theory is built on no arbitrary assumption. It is founded on the acknowledged principle of a repellent force subsisting between particles of caloric; and the circumstance of so many phenomena, otherwise inexplicable, admitting of being satisfactorily explained, upon the supposition that the operation of that force extends to all distances, demonstrates the truth of our conclusion.

But then, exclaims some spouting *ignoramus*, is not astronomy the most perfect of all sciences? Have not eclipses of the sun and moon been calculated and predicted for ages past, and for centuries to come, with the utmost certainty and precision? And how is it possible that a theory, which strikes at the root of all our preconceived notions regarding the cause of planetary motion, can be correct? Have all astronomical calculations and predictions turned out erroneous? I answer, no astronomical calculation or prediction, is in the least affected by any new hypothesis or theory contained in this volume. Astronomical phenomena are calculated, and predicted, from a knowledge of the actual moving velocities of different planetary bodies, without reference to the cause of centrifugal force. Our inquiries relate to the nature and cause of that force. The centrifugal movement of planetary bodies is an effect. The question, therefore, is, has that effect a cause; or has it not? According to the present almost universally received opinion regarding planetary motion, centrifugal force is ascribed to impulse originally communicated by Divine will and command, to planetary bodies, at a right angle to their centripetal tendencies, without the agency of any material or physical cause. Strip this explanation of its verbal disguise, and it is neither more nor less than saying, that the centrifugal movement of planetary bodies is an effect without a cause; whereas, I contend, and endeavour to show, that it is as much dependent upon the agency of a material cause as their centripetal tendencies.

The two first treatises in this volume were commenced with the intention of their being read at the late meeting of the British Association, at Liverpool. In writing, they so much exceeded in length what was anticipated, as to put the idea of reading them from beginning to end out of the question; and the novelty of their contents recommended them for publication. The author, however, agreeably to his original intention, was prepared to have read an abstract of the more important views contained in them, to the Physical and Mathematical Section. But this was also prevented, by his not being aware, that notice of papers intended to be read, must be sent to the general Secretary several weeks previous to the meeting. This circumstance has fortunately prevented the present publication being preceded by any garbled, and necessarily curtailed account, in newspaper reports, of the views it contains.

The author is aware, that there are a variety of other subjects collaterally related to some of those treated in this volume, of which no notice is taken. These subjects are reserved for future consideration; and should the views now presented to the public be deemed worthy of being printed, a second volume of a similar kind, and with a similar title, may at some future period make its appearance.

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ERRATA.

Page 5, line 3, for "rector," read "vector."
— 7, line 2, for "even," read "like."
— 115, line 7, for "for," read "towards."
— 142, line 22, for "rotation," read "revolution."

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AN ATTEMPT

TO EXPLAIN THE

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SECTION I.

STATEMENT OF THE COMMONLY RECEIVED OPINION REGARDING THE CAUSE OF PLANETARY MOTION.

Planetary motion is at present universally believed to be the result of the conjoint influence of two forces, denominated the Centripetal, and the Centrifugal. The cause of the former of these forces, is conceived to be a permanently inherent attractive influence, mutually subsisting between all particles of matter, whether near or distant from each other. And the law, usually called the law of gravitation, discovered by Sir Isaac Newton, by which this mutually attractive influence is governed, is, that *bodies attract each other with forces which increase directly with their masses, and inversely with the squares of their distances.*

That attraction is an inherent property of matter, which, without impulse, or any material line of communication, causes separate particles, and distant masses, to approach each other, is demonstrated by numberless facts. The approximating tendency of light bodies oppositely electrified, and of the opposite poles of magnetic needles, when presented to each other, afford visible exemplifications of it. The same property is manifested in the tendency of two drops of water, or of two globules of mercury, to rush together, and form one drop, or globule, upon being brought near each other, and even visibly before actual contact ensues. The tendency of drops of water while falling in rain, and of small quantities of mercury poured out on a flat surface, to assume a spherical figure, and the globular form of all planetary bodies, can only be explained, by having recourse to an inherent attractive property, which compels them to adopt this configuration, because this form admits of a nearer approximation of all the parts to the centre of attraction than any other. In like manner, the property of weight or gravity, which all bodies around us exhibit, is another proof, that a liability to be attracted by matter is the characteristic of every thing material.

That mutual attraction, according to the previously stated law of gravitation, subsists between different planetary bodies, and that it exerts an influence in producing and regulating planetary motion, has been satisfactorily ascertained. The variations observed in the height of the tides, according as the sun acts more or less in conjunction with, or in opposition to the moon, demonstrate that the earth is attracted both by the sun and the moon. And according to La Place, the circumstance of the radius vector of the planets describing equal areas in equal times, while revolving in elliptic orbits round the sun, shows that these bodies are constantly attracted towards the sun; and that the force by which they are attracted, diminishes as the square of the distance increases. The proportionality of the attractive force to the masses, is demonstrated, on earth, according to the same mathematician, by experiments on pendulums, the oscillations of which are of the same length, of whatever substance composed. And in the celestial regions, the same truth is demonstrated, by the constant relation which subsists between the periodic times of bodies revolving round a common focus, to the cubes of their mean distances from that focus. Thus, the squares of the periodic times which the different planets take to revolve round the sun, are proportional to the cubes of their mean distances from that luminary. And in like manner, the squares of the periodic times which the four satellites of Jupiter, and likewise which the seven satellites of Saturn, and the six of Uranus, severally take to revolve round their primary planets, are proportional to the cubes of the mean distances of their orbits from those planets.

It is obvious, that if matter were actuated by no other force but that of mutual attraction, planetary bodies, instead of revolving round each other, would rapidly concentrate into one undivided cohering mass. And from the amount of matter in the sun, which, according to La Place, is about 600 times greater than that contained in all the planets of the solar system put together, it has been calculated, that the different planets, if actuated by no other force but attraction, would fall to the sun from their mean distances, in the following times:—

Mercury, . . .	in 15 days	13 hours.
Venus, . . .	39	17
The Earth, . . .	64	13
Mars, . . .	121	10
Ceres, . . .	297	6
Pallas, . . .	301	4
Juno, . . .	354	19
Vesta, . . .	205	
Jupiter, . . .	765	19
Saturn, . . .	1901	
Georgium Sidus, . .	5425	

The moon would fall to the earth in 4 days 20 hours.

The law of gravitation is therefore inadequate to account for planets continuing to revolve in elliptic orbits round the sun, without any decrease in their mean distances from that luminary, unless it be assisted by some other force, acting, upon the supposition that planets revolve in circular orbits, at right angles to the centripetal, and duly proportioned thereto.

Supposing there was no obstructing medium, and no force acting upon matter but attraction, (as has been universally, though, as I will endeavour to show, erroneously, believed in regard to planetary bodies,) it can be demonstrated, that a body at a like distance from another, towards which it is gravitating, ~~even~~ the planets towards the sun, would continue for ever to revolve round it in a perfect circle, provided a projectile velocity, at right angles to the central attracting force, be communicated, equal in amount to what it would acquire by falling through half the radius of the circle towards the attracting body, by the force of gravity alone. A double projectile force always balances a quadruple power of gravity. Supposing, therefore, the same planetary body to be projected at two different distances from the sun, the one at the distance of 100 millions, and the other 200 millions of miles from that luminary; at the former distance, where its attraction would be 4 times as great as at the latter, it would require double the projectile velocity to make it revolve in a perfect circle, that it did at the latter.

If the projectile velocity be equal to what the body would acquire in falling through the whole radius of the circle by the force of gravity alone, its orbit would be a parabola, having the central attracting body for its focus. If the projectile velocity be greater than what is requisite to make its orbit a parabola, it would revolve in a hyperbola. If the projectile velocity be greater than the body would acquire by falling through half the radius of the circle, and less than it would acquire by falling through the whole radius of the circle, by the force of gravity alone, it would move in an elliptical orbit, the central attracting body being in one of its foci.

And according as the projectile velocity, within the above stated limits, exceeds what is requisite to make the projected body move in a perfect circle, so will the elliptical orbit in which it revolves be more eccentric. The last of these suppositions is conceived to be the case with all the planets and comets of the solar system. So far as has yet been ascertained, they all revolve round the sun in elliptical orbits, the eccentricities of which are very different: those in which planets and satellites revolve being nearly circular, while those described by comets are very eccentric.

SECTION II.

REFUTATION OF THE COMMONLY RECEIVED HYPOTHESIS REGARDING THE CAUSE OF CENTRIFUGAL FORCE IN PLANETARY MOTION.

The existence of a projectile velocity or centrifugal force, calculated, with the aid of the force of gravity, to perpetuate the movements of planetary bodies in elliptical orbits, is a point that admits of no doubt. Till recently, however, nothing deserving to be called a theory, or hypothesis, purporting an explanation of the origin or cause of this force or velocity, existed. Unlike the centripetal tendency, which was proven to result from an attractive influence subsisting between, and permanently inherent in, all ponderable materials, its origin or existence was never ascribed to any inherent property of matter, nor to any material cause. It was supposed to be an impulse, or projectile velocity, originally communicated to planetary bodies by divine will and command. And as these bodies were conceived to revolve in their orbits through space in which nothing material existed to obstruct their motion, such original impulse, when aided by a constant centripetal force, was calculated, without any renewal, or subsequent repetition, not only to prevent their mutual attraction producing any permanent approximation, but for ever to perpetuate the existing planetary movements.

The preceding explanation of the cause of centrifugal velocity is liable to insurmountable objections. It is a mere assumption, resting on no evidence whatever, and supported by nothing analogous in nature. In fact, it seems to have been adopted for want of any other explanation, solely on the ground of convenience, in consequence of the power of gravity requiring the assistance of such a force, in order to account for the revolution of planetary bodies in elliptical orbits, agreeably to the relation discovered by Kepler, between their periodic times, and their mean distances from the sun.

The mean distances of the planets and comets from the sun are so exceedingly diversified, that no relative proportion between them can be pointed out. To account, therefore, for the strict relation subsisting between their moving velocities and their mean distances from the sun, agreeably to the hypothesis under consideration, would require us to admit, that the amount of original impulse severally communicated to them, had been equally diversified, and equally devoid of all relative proportion. Planets, according as they were destined to revolve in orbits nearer the sun, would require to have been originally impressed by stronger centrifugal impulses. And in like manner, the different satellites, in revolving round their primary planets, must have received a stronger centrifugal impulse, according as they were destined to revolve in smaller orbits. Besides, the centrifugal velocity of rotation exhibited by planetary bodies, is even devoid of any proportionality to their mean distances from the sun. And instead of being less rapid, according as planets are more distant from the sun, and move more slowly in their orbits, (as might have been expected, if rotation had derived its existence from an original projectile impulse,) it bears a nearer approximation to an inverse ratio. Those planets which are farthest distant from the sun, and which move slowest in their orbits, appear to revolve most rapidly on their axes. Surely it need hardly be remarked, that such arbitrary diversity in the mode of generating planetary motion, is incompatible with the simplicity and unity visible in all the other designs of Nature. And a hypothetical explanation of the cause of centrifugal velocity, which requires such variety, and yet such precision, in adjusting the amount and direction of impulse, without any other evidence than convenience and arbitrary supposition to support it, is totally inadmissible.

Again, a hypothesis which explains planetary motion, by requiring us to admit the original communication of a force different from those which nature employs in any other of her operations, is improbable, in so far as it departs from the analogies of nature. In every other instance where motion takes place naturally, it appears to result from some inherent or existing adequate cause, and not from the arbitrary communication of impulse. If nature employed impulse in producing the tides in the ocean, or the winds in the atmosphere, it would be no departure from the analogies of nature to suppose, that centrifugal force was also the result of original impulse. But instead of impulse being the cause of the tides in the ocean, it has been demonstrated, that they result from the attractive property inherent in matter contained in the sun and moon. And in like manner, aerial currents can be demonstrated to be results of a disturbance of the atmospheric equilibrium, caused, not by impulse, but by the unequal expansion of air, arising from simultaneous inequalities of temperature, and of unequal amounts of moisture simultaneously evaporated and condensed, in different localities. Nature, in conducting all her operations, employs attractive or repulsive properties, which are proven to be permanently inherent in, inseparable from, and equally indestructible with the materials themselves, from the fact, that the same kind of matter, in the same relative circumstances, is always actuated in the same manner. The science of chemistry affords innumerable instances of this being the fact. All the compositions and decompositions of bodies going on around us naturally, or which can be effected by artificial means, depend, not upon original impulse, but upon attractive or repulsive properties mutually subsisting between, and permanently inherent in, the materials themselves. And the chemist has no other power of effecting the decomposition or composition of bodies, but by bringing different ponderable and imponderable substances into such juxtaposition, that the various attractive and repulsive relations subsisting between their particles, and which have been originally conferred upon them by the hand of their Creator, may be brought into operation, and accomplish the intended purpose.

From the preceding observations it is obvious, that to suppose that original impulse is the cause of centrifugal force, is a mere assumption, resting on no evidence whatever; and instead of being supported, is actually contradicted by every thing analogous in nature. Besides, when it is admitted that the centripetal force originates not in impulse, but in the mutual attraction of matter; to disbelieve that nature employs impulse in generating centrifugal force, is no more sacrilege, than it was in the time of Torricelli, to call in question the doctrine, then universally received, of nature abhorring a vacuum, advanced in order to account for the water following a piston in a water-pump.

SECTION III.

STATEMENT AND REFUTATION OF THE THEORY WHICH SUPPOSES THAT CENTRIFUGAL FORCE, AS WELL AS PLANETARY SYSTEMS, ORIGINATE FROM THE GRADUAL CONDENSATION OF NEBULOUS MATTER WIDELY DIFFUSED THROUGHOUT SPACE.

Recently a theory, supposed to explain the origin of centrifugal force, has been founded on the supposed gradual condensation of large quantities of widely diffused nebulous matter, seen by Sir William Herschel with the aid of telescopes. I shall here insert a brief description of these nebulæ, with an account of the theory above alluded to, extracted from Chambers' Edinburgh Journal, No. 263, page 17.

"To these luminous objects the term *nebula*, or *nebulous matter*, is applied, in consequence of their so often resembling the light fantastic clouds which occasionally mottle the summer sky. No familiar object, except, perhaps, the piece of bread which we tear from a roll to serve as a mouthful, could be adduced as conveying an adequate idea of the utter irregularity of the forms of some of these objects. In those which are so irregular in form, there is an approach to an equal degree of luminousness over the mass. But there are others, in which the mass presents parts of considerable brightness; others, again, in which the brighter parts appear like *gatherings* of the luminous matter,—an appearance not unlike that of a screen behind which several candles are burning. Others there are, again, in which these comparatively bright spots seem nearly disengaged from the surrounding matter, or only bedded on a slight back-ground composed of it. In a fifth class, the separation of the spots has proceeded further; and these spots, let it be observed, are of a spherical form. Connecting the last set of objects with an order of stars which are surrounded by a slight *bur* of nebulous matter, Sir William Herschel conceived himself to have traced the whole process of the formation of the stellar spheres, from a diffused luminous mass, to the condition of a defined orb, of the character of our sun.

"This supposed process of condensation, strange to say, supplies a rule for such a rotatory motion as that of our sun. When fluid particles flow towards a centre, they almost invariably form a whirl or vortex. The sinking of water through a funnel illustrates this principle to the most common perceptions. But there are such things as binary stars—that is, sets of two, which revolve round each other. So may we suppose the nebulous matter, in certain cases, to assume that arrangement. On the surface of a flowing stream, in which slight repulsions of water from the banks produce many little eddies, how common is it to see two of those miniature whirlpools come within each other's influence, and then go on wheeling round each other: *precisely in that manner* do the two suns of a binary star carry on their revolutions.

In fact, just as our globe is sustained in space by the same law which causes an apple to fall to the ground, so do these great spheres appear to have been set in motion by the same simple law, which every minute is causing straws and feathers to dance in fairy rings on the pathway before us.

"And not only are the formation and movements of suns to be thus accounted for, but the same laws explain how a whole planetary system may be made up. As the process of condensation in a nebular mass proceeds, the whirling motion must always become more rapid, just as a sling, when the string is allowed to wind up round our finger, flies always the faster as the string shortens. While the rotatory motion is thus increasing, the centrifugal force may become too great to permit the outer, and probably softer, portion to adhere to the mass; and this outer and softer portion will therefore be left off as a ring surrounding the principal mass at a little distance. Other portions may thus be successively detached, till a considerable number of rings will be left encircling the central mass. Only, if the matter of these rings be of an uniform character, can it be expected that they should continue as rings. Almost necessarily, there will be inequalities in their composition, causing them to break up into pieces, each of which, by virtue of gravity, will then collapse into a sphere. A sphere, thus formed, must needs retain the same revolutionary motion as the ring of which it once formed a part, and at the same time it must acquire a rotatory motion in the same direction. Thus we have a set of primary planets, the bodies of which have only to undergo the same processes as the central mass, in order to throw off satellites. The two rings which surround Saturn appear an example of two exterior portions of that planet as yet not advanced from the intermediate state, but which may in time become additions to the number of his satellites. There is also, in our own system, a certain residue, as it may be called, of the nebulous matter, which surrounds the sun to a point beyond the orbit of Mercury, though not in all circumstances to be detected. This residue is of extreme thinness, and does not surround the sun in any direction, except in the plane of the planetary movements. It is occasionally visible, as a conical mass of light, shooting up from the place where the sun has just set, and in the oblique direction of his course. It is termed by astronomers the *zodiacal light*, and may be identical with that resisting medium, of the existence of which the retardations of Encke's comet have recently produced a general conviction among astronomers."

The inadequacy of the preceding theory to account for centrifugal force is obvious, and the importance attached to it by the writer of the above extract, seems to be but ill merited. If the gradual condensation of nebulous matter originated exclusively in its mutual attraction, the production of rotatory motion, like that of our sun revolving on its axis, is by no means a consequence so necessary, or likely to occur, as is above imagined. And the weak analogies upon which the theory is founded, such as that of fluid particles flowing towards a centre almost invariably forming a whirl or vortex, is any thing but satisfactory reasoning. Supposing a nucleus of nebulous matter already formed by attraction, it is obvious, according to mechanical principles, that every other particle or portion of nebulous matter attracted thereby, would move towards it, if actuated by no other force, in the direct line of its centre of attraction; and upon forming a union with it in that line, it is not easy to perceive how it could generate rotation, provided the nucleus had no such motion before. And provided it previously had a rotatory motion, every addition to the nucleus, resulting from the attraction of matter towards it in the direction of its centre, instead of increasing the rotatory velocity, would diminish it, in so far as the revolving nucleus would have part of its rotatory velocity lost, in consequence of having to communicate a portion thereof to that added matter which had not it before. In like manner it is obvious, that unless every addition of nebulous matter fell upon the surface of the revolving nucleus, not only with greater velocity than it was revolving, but also in the direction of its revolution, it is physically impossible that it could increase its rotatory velocity. And it is equally obvious, that if additional nebulous matter fell upon the surface of the revolving nucleus, either with less velocity than that with which it was revolving, or in any direction different from that in which its surface revolved, (which, in the process of condensation of an irregularly formed nebulous mass of matter by attraction, is more likely to happen than that it should fall upon it in the direct line of the revolution of its surface,) it would necessarily tend more or less to diminish its rotatory motion.

Even the analogical reasoning adduced in support of this portion of the theory, seems to be founded on a misconception of the cause of whirls and eddies in fluids. All whirls and eddies produced in streams, are occasioned by neighbouring portions of the water acquiring unequal velocities. Such may arise from inequalities either in the impetus, or in the obstructions, to which its different portions are subjected; or from being impelled against an opposing obstacle of a curved configuration, at an angle calculated to generate rotatory motion. The greater proximity of one portion of the water to a stationary or obstructing obstacle, such as the banks or beds of streams present, affords an exemplification of the former of these causes of eddies and whirls. And the curved configuration of banks, and sunken rocks, and the pouring of liquids into funnels, afford examples of the latter.

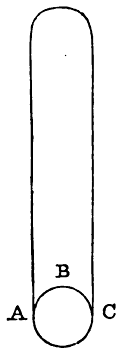
The portion of the theory which relates to the projection of planets by the sun's centrifugal velocity becoming too great to permit the outer, and probably softer portion, to adhere to the mass; and the idea of planets throwing off satellites upon the same principle, is exceedingly whimsical, and easily disproved in various ways. We will advert to some of these.

According to Sir John Herschel, the centrifugal force produced at the equator by the rotation of the earth on its axis, is only a 289th part of the force, or weight, by which all bodies, whether solid or liquid, tend to fall towards the earth; and only diminishes their weight to that extent. Consequently, before the earth could throw off fluid matter from its surface to form the moon, agreeably to the theory under consideration, it would require a rotatory velocity on its axis, which would diminish the weight of fluids at the equator 289 times more than they are by the present rotatory motion. Now, there is no evidence whatever that the earth ever revolved on its axis more rapidly than it does at present. And even were it admitted that it did revolve at some former period more rapidly than it now does, the theory under consideration, in so far as it assigns no reason for the retardation of its rotatory motion, is inadequate, in its present shape, to account for the existing phenomena. Similar objections are applicable to the idea of the sun throwing off planets; and of other planets, besides the earth, throwing off satellites.

Again, if the matter which at present constitutes the different planets of the solar system, had acquired its centrifugal velocity by being projected from the sun, in consequence of the rapid rotatory motion of that luminary; it is reasonable to suppose, that those planets which revolve in orbits at the greatest distance from the sun, must have been projected with the greatest force; and consequently, should continue to revolve through empty unobstructing space with the greatest velocity. Now, instead of this being the case, the very reverse is the fact. The moving velocity of all planets in their orbits round the sun, is, agreeably to a certain ratio, less as their mean distance from the sun becomes greater. Thus, according to Sir John Herschel, the moving velocity of Mercury in its orbit is about 109,400 miles per hour; whereas that of Venus is only 80,060; and that of the earth only 68,080 miles per hour. Similar objections to the theory of centrifugal force under consideration, may be deduced from the moving velocities of satellites in their orbits round their primary planets. The satellites of Jupiter, which revolve in orbits at the greatest distance from their primary planet, and which, according to this projectile theory of centrifugal velocity, must have been thrown off with the greatest force, instead of moving in their orbits with the greatest velocity, as the theory under consideration would lead us to expect, actually move with the least. And in like manner, the satellites of Saturn, and of Uranus, move through space with less velocity, according as their orbits are more remote from the primary planet to which they are attached.

Again, if the centrifugal velocity of the planets in their orbits was owing solely to the matter of which they are composed having been projected from the sun, in consequence of the too rapid rotation of that luminary on its axis, the moving velocity of the planets in their orbits, ought not to be greater than the rotatory velocity of the equatorial regions of the body from which they had been projected. Now, what is the fact? The rotatory velocity of the equatorial regions of the sun is only about 4,700 miles an hour, whereas the moving velocity of Mercury in its orbit is 109,400; that of Venus, 80,060; and that of the earth 68,080 an hour.

But the fact which most completely demonstrates the incorrectness of the theory under consideration is, that the figure of the orbits in which comets and planets revolve round the sun, could not, by any possibility, be the result of a projectile velocity arising out of the too rapid rotatory movement of the sun, aided by no other force but that of attraction subsisting between all kinds of matter. Matter projected from the surface of the sun, in consequence of its too rapid rotatory motion, could only be projected in a straight line at a tangent to that luminary. And all the influence which the attractive force of the sun could have in making it bend from the straight line of projection into the form of an orbit, would be to cause it to return in a line so curved, as would make it strike the opposite side of the sun to that from which it had been projected. In short, there is no possibility of getting rid of the objection to the theory under consideration, that matter projected from the sun in any way whatever, if acted upon, subsequent to projection, by no other force but that of attraction, must inevitably return to the sun again. Suppose the annexed figure to be the sun revolving on its axis in the direction of A B C. If matter be projected from its surface at A, with sufficient force to overpower the sun's attraction for any considerable length of time, and be acted upon, subsequent to projection, by no other force but the sun's attraction, it must inevitably return to the sun again, so as to strike it at C, after performing a circuit similar to that in the margin, and which would be more elongated, according as the force of projection was greater. This theory, therefore, is totally inadequate to account, not only for the nearly circular ellipses in which planets revolve round the sun, and in which satellites revolve round their primary planets; but even inadequate to account for the very eccentric elliptical orbits in which comets revolve round the centre of the system.



Having thus brought forward a sufficiency of objections to show that the existing theories, relative to the origin or cause of the centrifugal velocity of planetary bodies, are either exceedingly improbable, or totally inadequate to account for the phenomena; we will now proceed to make some preliminary observations, in order to explain several circumstances, more or less connected with the new theory we are about to advance, as a substitute for those we have been endeavouring to refute.

SECTION IV.

OBSERVATIONS ON THE ATTRACTIVE AND REPULSIVE PROPERTIES OF PONDERABLE AND IMPONDERABLE MATERIALS.

Judging from the relation subsisting between the periodic times of the planets and their mean distances from the sun, I have been led to suspect that the centrifugal, like the centripetal force, depends upon some influence exerted upon planetary bodies by the sun. And as we have no evidence that nature ever employs any influences but those of attraction and repulsion, which seem to be properties permanently inherent in matter, I am inclined to think that all planetary motion results from, and is maintained by, such a distribution of materials possessed of one or both these properties, as is calculated to produce the observed effect. Our distance from the sun precludes us from examining the materials of which it is composed, or of ascertaining their comparative attractive or repulsive relations. From analogy, however, we may infer, that it is composed of materials, the general properties of which are similar to those of substances composing the crust of the earth. We will, therefore, now proceed to examine the attractive and repulsive relations, which the various substances around us present towards each other; and, in the next Section, will draw some inferences relative to the general distribution and arrangement of the ponderable and imponderable materials of which the earth is composed, and the influences by which they are mutually affected, and which, from analogy, may be extended to other planetary bodies. And thereafter, upon the supposition that the sun and other planetary bodies are composed of substances possessed of similar properties to those of which the earth consists, and which act upon each other, and upon like substances, not only in the same, but in every other planetary body, however distant, with forces which increase directly with the masses, and inversely with the squares of the distances, we will endeavour to show, that, by the action of the mutual attractive and repulsive relations subsisting between such substances, planetary motion, in all its details, including both the centripetal and centrifugal forces, may be accounted for.

The various material substances, composing the crust of the earth, have been divided into two classes, denominated Ponderable, and Imponderable. The former comprehends the fifty-eight elementary substances capable, as the name implies, of being weighed. The latter, so far as is yet known, is limited to three substances; viz. heat, light, and electricity, (magnetism and electricity being considered identical,) which are incapable of being weighed. Now, the only forces inherent in these different kinds of matter, are attraction and repulsion. Attraction subsists between all ponderable materials, and also between ponderable and imponderable bodies. Repulsion subsists between the homogeneous particles of the three imponderable substances; and probably also between the particles of the different imponderable bodies, except those of the same denomination, such as the vitreous and resinous electricities, which are mutually attractive.

We have already adduced sufficient evidence that attraction subsists between all ponderable materials around us; and that the same force also extends to the different planetary bodies of the solar system, so as to exert an influence in producing and regulating their orbitual movements. Upon this point, therefore, it is unnecessary to make any farther remarks.

That attraction mutually subsists between caloric and ponderable materials, may be inferred as probable from various circumstances; but is established by the fact ascertained by Dr. Crawford, that atmospheric air of the usual density, has a greater capacity for caloric than a vacuum. This could not be the case, unless an attractive force subsisted between caloric and aerial particles, so as in part to counteract the tendency of caloric to diffuse itself equally throughout space, by means of its repellent property. The same truth is demonstrated, by the unequal capacities for caloric of similar bulks of all different substances. Thus, water has a greater capacity for caloric than an equal bulk of any solid substance known; and even a greater capacity than atmospheric air, not only when estimated by bulk, but also when estimated by weight.

That different ponderable substances exert different degrees of attractive force for caloric, may be inferred as probable from the remarkable difference in the density of bodies at similar temperatures. A similar inference may be deduced from the want of any strict relation subsisting between the densities of bodies, and their capacities for caloric, as is strikingly exemplified in the case above alluded to, of the calorific capacity of water compared to that of other substances.

That the particles of caloric are mutually repellent may be inferred from the following circumstances: the first of which might likewise be adduced in order to prove, that the particles of light, and also those of electricity, are possessed of a similar repellent property towards each other. 1*st.* The particles of caloric are never found cohering, or aggregated, so as to present a body possessed of sensible magnitude. 2*d.* Though an accumulation of caloric may be artificially concentrated at any given place, still, it is ever tending to diffuse and distribute itself, according to the laws that regulate the equalization of temperature. 3*d.* The distribution of caloric around us is such, or is ever tending thereto, that heating bodies does not materially increase, nor detract from, their weight. From these circumstances, severally and conjointly, it may be inferred as probable, that a repellent force mutually subsists between the particles of caloric. The truth of the inference, however, is satisfactorily demonstrated by the following experiment.

If a bladder, half inflated, be placed in the receiver of an air-pump, it will gradually expand as the air around it is withdrawn; and again contract upon its re-admission. This experiment shows that some repellent property exists in a state of union with the aerial particles. And that this property resides in the caloric held in affinity by the aerial particles, is evident from the fact, that the half-inflated bladder expands with the rising, and contracts with the sinking of temperature, just as it does with increase and diminution of external atmospheric pressure, upon the withdrawal, and re-admission of the air around it by means of the air-pump. That the caloric absorbed by bodies, upon being heated, does not actually fill the additional space occupied by their expansion, is obvious from the circumstance of different substances undergoing very different degrees of expansion, upon absorbing similar amounts of caloric. The same truth is also evident from the expansibility of even the same substance varying with difference of temperature: liquids, for instance, become more expansible as they approach their boiling heat.

That caloric and the other imponderable bodies are mutually repellent, may be inferred as probable, from their simultaneous and mutual evolution of each other; but the evidence upon this point is by no means so satisfactory, as that regarding the mutual repulsion subsisting between the particles of caloric. Indeed, I am almost inclined to think, that the various phenomena adduced in support of the opinion that caloric and light are mutually repellent, might be as satisfactorily accounted for upon the supposition, that caloric and light are unequally attracted, and consequently held in affinity in unequal proportions, by different ponderable substances; and instead of a repellent force, that some degree of attraction subsists between the particles of caloric and those of light, though the attractive force thus mutually subsisting between them, is weaker than the repellent force subsisting between the homogeneous particles of either substance. Agreeably to this hypothesis, we see a reason why any ponderable body, containing a proportion of the one substance, should always contain a greater or less proportion of the other; and also, why an evolution of the one substance, should always be accompanied with a greater or less evolution of the other. The phenomena of ignition and combustion are more in accordance with this hypothesis, than with the one commonly received; but upon this point we will not farther insist. The following facts constitute the evidence usually adduced in support of the hypothesis, that caloric and light are mutually repellent. Light is evolved in all cases of combustion. All solids emit light, (that is, red heat commences,) when the temperature is raised to about 800° of Fahrenheit. A diamond when heated emits light in the dark. Likewise all pyrophori (that is, substances, which, upon exposure to light, absorb it, and for some time afterwards continue to evolve it in the dark) give out light more copiously, but sooner cease to do so, by increasing their temperature; and *vice versa.* In order to explain these and similar phenomena, it has been inferred, that caloric exerts a repellent force towards light.

That light repels caloric is considered probable, from the fact of forces subsisting between bodies, so far as has been ascertained in other cases, being mutual. Thus, attractive forces exerted between ponderable materials are proven to be mutual, by the circumstance of two or more bodies attracting each other, with forces proportioned to the amount of matter they severally contain. Now, if the attractive force subsisting between ponderable bodies be mutual, it is reasonable, judging from analogy, to suppose, that the repellent force subsisting between different imponderable bodies is also mutual. And accordingly, if caloric repels light, it may be presumed that light repels caloric.

That caloric and electricity, and light and electricity, are mutually repellent may be inferred as probable from the fact, that the electric fluid, in passing through substances in the concentrated form of lightning, evolves both heat and light.

That the homogeneous particles of electricity repel each other, is satisfactorily demonstrated in the common experiment of pith balls separating when similarly electrified; and also in the mutual recession of similar poles of magnetic needles. That the heterogeneous particles of electricity attract each other, is equally satisfactorily demonstrated by the approximation of pith balls oppositely electrified; and also by the approximation of the opposite poles of magnetic needles, even when separated from each other by being severally enclosed in glass cases. And from the fact of the two electricities never being found so concentrated as to present a solid tangible shape, it may be inferred, that the repellent force mutually subsisting between the particles both of vitreous and of resinous electricity, is stronger than the attractive force mutually subsisting between the vitreous and resinous particles, (for otherwise equal proportions of each kind would concentrate into the solid state,) but how much stronger we have no means of determining.

SECTION V.

EXPLANATORY INFERENCES DEDUCED FROM A CONSIDERATION OF THE RELATIVE ATTRACTIVE AND REPULSIVE PROPERTIES OF PONDERABLE AND IMPONDERABLE MATERIALS.

If the attractive and repulsive properties conferred originally upon different substances be inseparable therefrom, and equally indestructible with the materials themselves, (as there is reason to believe is the case,) every kind of matter, whether ponderable or imponderable, must be permanently the same, whether it exists separately or in a state of combination with other substances; and must be at all times exerting the same attractive or repulsive relations towards other substances, whether near or distant. One substance may exert different degrees of attractive force towards different substances; but towards the same substance, the amount, and kind of force exerted, must be always the same at the same distance. And the only modification produced upon these attractive and repulsive relations by difference in the quantity of matter possessed of one, or both these properties; or by difference in the distance of the materials from each other, is in conformity with the law of mass and distance, which, to include repulsion, as well as attraction, and the moving velocities to which they give rise, may run in the following terms:—

Attractive and repulsive forces inherent in matter, and the velocities which they communicate, increase directly as the masses which produce them, and inversely as the squares of the distances at which they act.

In accordance with the attractive and repulsive properties inherent in the different ponderable and imponderable substances which we have pointed out, we will now proceed to draw some inferences composing the crust of the earth. We will, therefore, now proceed to examine the attractive and repulsive relations, which the various substances around us present towards each other; and, in the next Section, will draw some inferences relative to the general distribution and arrangement of the ponderable and imponderable materials of which the earth is composed, and the influences by which they are mutually affected, and which, from analogy, may be extended to other planetary bodies. And thereafter, upon the supposition that the sun and other planetary bodies are composed of substances possessed of similar properties to those of which the earth consists, and which act upon each other, and upon like substances, not only in the same, but in every other planetary body, however distant, with forces which increase directly with the masses, and inversely with the squares of the distances, we will endeavour to show, that, by the action of the mutual attractive and repulsive relations subsisting between such substances, planetary motion, in all its details, including both the centripetal and centrifugal forces, may be accounted for.

The various material substances, composing the crust of the earth, have been divided into two classes, denominated Ponderable, and Imponderable. The former comprehends the fifty-eight elementary substances capable, as the name implies, of being weighed. The latter, so far as is yet known, is limited to three substances; viz. heat, light, and electricity, (magnetism and electricity being considered identical,) which are incapable of being weighed. Now, the only forces inherent in these different kinds of matter, are attraction and repulsion. Attraction subsists between all ponderable materials, and also between ponderable and imponderable bodies. Repulsion subsists between the homogeneous particles of the three imponderable substances; and probably also between the particles of the different imponderable bodies, except those of the same denomination, such as the vitreous and resinous electricities, which are mutually attractive.

We have already adduced sufficient evidence that attraction subsists between all ponderable materials around us; and that the same force also extends to the different planetary bodies of the solar system, so as to exert an influence in producing and regulating their orbitual movements. Upon this point, therefore, it is unnecessary to make any farther remarks.

That attraction mutually subsists between caloric and ponderable materials, may be inferred as probable from various circumstances; but is established by the fact ascertained by Dr. Crawford, that atmospheric air of the usual density, has a greater capacity for caloric than a vacuum. This could not be the case, unless an attractive force subsisted between caloric and aerial particles, so as in part to counteract the tendency of caloric to diffuse itself equally throughout space, by means of its repellent property. The same truth is demonstrated, by the unequal capacities for caloric of similar bulks of all different substances. Thus, water has a greater capacity for caloric than an equal bulk of any solid substance known; and even a greater capacity than atmospheric air, not only when estimated by bulk, but also when estimated by weight.

That different ponderable substances exert different degrees of attractive force for caloric, may be inferred as probable from the remarkable difference in the density of bodies at similar temperatures. A similar inference may be deduced from the want of any strict relation subsisting between the densities of bodies, and their capacities for caloric, as is strikingly exemplified in the case above alluded to, of the calorific capacity of water compared to that of other substances.

That the particles of caloric are mutually repellent may be inferred from the following circumstances: the first of which might likewise be adduced in order to prove, that the particles of light, and also those of electricity, are possessed of a similar repellent property towards each other. 1*st*. The particles of caloric are never found cohering, or aggregated, so as to present a body possessed of sensible magnitude. 2*d*. Though an accumulation of caloric may be artificially concentrated at any given place, still, it is ever tending to diffuse and distribute itself, according to the laws that regulate the equalization of temperature. 3*d*. The distribution of caloric around us is such, or is ever tending thereto, that heating bodies does not materially increase, nor detract from, their weight. From these circumstances, severally and conjointly, it may be inferred as probable, that a repellent force mutually subsists between the particles of caloric. The truth of the inference, however, is satisfactorily demonstrated by the following experiment.

If a bladder, half inflated, be placed in the receiver of an air-pump, it will gradually expand as the air around it is withdrawn; and again contract upon its re-admission. This experiment shows that some repellent property exists in a state of union with the aerial particles. And that this property resides in the caloric held in affinity by the aerial particles, is evident from the fact, that the half-inflated bladder expands with the rising, and contracts with the sinking of temperature, just as it does with increase and diminution of external atmospheric pressure, upon the withdrawal, and re-admission of the air around it by means of the air-pump. That the caloric absorbed by bodies, upon being heated, does not actually fill the additional space occupied by their expansion, is obvious from the circumstance of different substances undergoing very different degrees of expansion, upon absorbing similar amounts of caloric. The same truth is also evident from the expansibility of even the same substance varying with difference of temperature: liquids, for instance, become more expansible as they approach their boiling heat.

That caloric and the other imponderable bodies are mutually repellent, may be inferred as probable, from their simultaneous and mutual evolution of each other; but the evidence upon this point is by no means so satisfactory, as that regarding the mutual repulsion subsisting between the particles of caloric. Indeed, I am almost inclined to think, that the various phenomena adduced in support of the opinion that caloric and light are mutually repellent, might be as satisfactorily accounted for upon the supposition, that caloric and light are unequally attracted, and consequently held in affinity in unequal proportions, by different ponderable substances; and instead of a repellent force, that some degree of attraction subsists between the particles of caloric and those of light, though the attractive force thus mutually subsisting between them, is weaker than the repellent force subsisting between the homogeneous particles of either substance. Agreeably to this hypothesis, we see a reason why any ponderable body, containing a proportion of the one substance, should always contain a greater or less proportion of the other; and also, why an evolution of the one substance, should always be accompanied with a greater or less evolution of the other. The phenomena of ignition and combustion are more in accordance with this hypothesis, than with the one commonly received; but upon this point we will not farther insist. The following facts constitute the evidence usually adduced in support of the hypothesis, that caloric and light are mutually repellent. Light is evolved in all cases of combustion. All solids emit light, (that is, red heat commences,) when the temperature is raised to about 800° of Fahrenheit. A diamond when heated emits light in the dark. Likewise all pyrophori (that is, substances, which, upon exposure to light, absorb it, and for some time afterwards continue to evolve it in the dark) give out light more copiously, but sooner cease to do so, by increasing their temperature; and *vice versa*. In order to explain these and similar phenomena, it has been inferred, that caloric exerts a repellent force towards light.

That light repels caloric is considered probable, from the fact of forces subsisting between bodies, so far as has been ascertained in other cases, being mutual. Thus, attractive forces exerted between ponderable materials are proven to be mutual, by the circumstance of two or more bodies attracting each other, with forces proportioned to the amount of matter they severally contain. Now, if the attractive force subsisting between ponderable bodies be mutual, it is reasonable, judging from analogy, to suppose, that the repellent force subsisting between different imponderable bodies is also mutual. And accordingly, if caloric repels light, it may be presumed that light repels caloric.

That caloric and electricity, and light and electricity, are mutually repellent may be inferred as probable from the fact, that the electric fluid, in passing through substances in the concentrated form of lightning, evolves both heat and light.

That the homogeneous particles of electricity repel each other, is satisfactorily demonstrated in the common experiment of pith balls separating when similarly electrified; and also in the mutual recession of similar poles of magnetic needles. That the heterogeneous particles of electricity attract each other, is equally satisfactorily demonstrated by the approximation of pith balls oppositely electrified; and also by the approximation of the opposite poles of magnetic needles, even when separated from each other by being severally enclosed in glass cases. And from the fact of the two electricities never being found so concentrated as to present a solid tangible shape, it may be inferred, that the repellent force mutually subsisting between the particles both of vitreous and of resinous electricity, is stronger than the attractive force mutually subsisting between the vitreous and resinous particles, (for otherwise equal proportions of each kind would concentrate into the solid state,) but how much stronger we have no means of determining.

SECTION V.

EXPLANATORY INFERENCES DEDUCED FROM A CONSIDERATION OF THE RELATIVE ATTRACTIVE AND REPULSIVE PROPERTIES OF PONDERABLE AND IMPONDERABLE MATERIALS.

If the attractive and repulsive properties conferred originally upon different substances be inseparable therefrom, and equally indestructible with the materials themselves, (as there is reason to believe is the case,) every kind of matter, whether ponderable or imponderable, must be permanently the same, whether it exists separately or in a state of combination with other substances; and must be at all times exerting the same attractive or repulsive relations towards other substances, whether near or distant. One substance may exert different degrees of attractive force towards different substances; but towards the same substance, the amount, and kind of force exerted, must be always the same at the same distance. And the only modification produced upon these attractive and repulsive relations by difference in the quantity of matter possessed of one, or both these properties; or by difference in the distance of the materials from each other, is in conformity with the law of mass and distance, which, to include repulsion, as well as attraction, and the moving velocities to which they give rise, may run in the following terms:—

Attractive and repulsive forces inherent in matter, and the velocities which they communicate, increase directly as the masses which produce them, and inversely as the squares of the distances at which they act.

In accordance with the attractive and repulsive properties inherent in the different ponderable and imponderable substances which we have pointed out, we will now proceed to draw some inferences relative to their general distribution and arrangement as constituents of the earth, and which, from analogy, may be extended to other planetary bodies. And though it is probable that the repellent force mutually subsisting between all the imponderable substances contained in the different planetary bodies, exerts an influence in maintaining their separation, and in producing and regulating their movements through space; still, as the distribution and movements of caloric, and its repellent influence, are better ascertained than those of light and electricity, our farther observations will be principally restricted to the former of these substances, and only by tacit conjecture extended to the others.

It is impossible to produce a perfect separation of ponderable from imponderable matter. For instance, it is out of our power to separate caloric from any ponderable substance: we may diminish its quantity, but cannot separate it entirely. The most simple ponderable body whose properties we can subject to examination, is therefore a compound. It consists of at least one ponderable substance in combination with caloric, and probably with other imponderable materials. Now, as each substance is constant in the degree of attractive or repulsive force which it exerts towards every other; and as all ponderable bodies subjected to our examination are compounds of ponderable and imponderable materials, the former being mutually attractive, and the latter mutually repulsive, it follows: 1*st*.

That all the phenomena of attraction and repulsion mutually subsisting between different ponderable atoms, or different ponderable masses composed of an aggregation of atoms, result from differences in the aggregate effect of the attractive and repulsive forces, mutually subsisting between their respective ponderable and imponderable constituents. 2*d*. That approximation and recession of the particles of bodies around us, (the former of which is exemplified in the approximation of the particles of solids and liquids when their temperature is reduced; and the latter in the mutual recession of gaseous particles when they are heated, or when they are rarefied and relieved from atmospheric pressure by means of the air-pump,) result from the preponderance of one of these forces over the other; and a state of rest results from their equilibrium.

From these principles we infer that gravitation and gravity, (the former being the act of bodies tending towards each other, and the latter the necessary consequence of the preponderance of attraction which produces this tendency,) *are results, not merely, as has been hitherto supposed, of the preponderance of the mutual attraction of ponderable matter in one direction over every other, but of the preponderance of the conjoint attractive forces of the several ponderable and imponderable constituents of bodies, over the mutual repellent forces of their several imponderable constituents.* The gravitation of bodies composed of ponderable and imponderable materials, such as those around us, towards the earth's centre, proves that the attractive forces exerted upon them by the aggregate mass of ponderable and imponderable substances, of which the earth is composed, preponderate over the repulsive; and the weight which they exhibit is the measure of that preponderance.

Though a certain class of bodies have been distinguished as being ponderable, weight is not one of their inherent properties: for the weight of the same body may vary, or even entirely disappear, with mere change of place. The weight of any given body is greatest at the surface of a sphere, such as that of the earth, and gradually diminishes towards its centre, where the amount of matter, and the preponderance of attractive over repulsive force to which it gives rise, being equal in every direction, a body can have no weight; except, of course, what belongs to the sphere as a whole, and which is also neutralized by its revolutionary movement in its orbit. On the same principle it is inferred, that weight increases with the size and density of the sphere. Thus it has been calculated by La Place, that a body, which, at the earth's equator, weighs one pound, at Jupiter's equator (after allowing for the inferior density of that planet) would weigh 2·509 pounds; and at that of the sun 27·65 pounds.* In receding externally from the surface of a sphere, the weight of bodies diminishes according to the law of distance. Thus, it has been calculated, that a body, weighing a thousand pounds at the earth's surface, would be attracted by the earth with a force of only five ounces; or, in other words, would weigh only five ounces, if removed as far as the moon's orbit. Weight, or gravity, therefore, is not a distinct, inherent quality, which a body exhibits unassisted, and spontaneously of itself, but an effect produced upon it by other bodies. It consists in the preponderance of the attractive over the repulsive influences exerted upon the body weighed, being greater in one line, than in any other, either in consequence of the greater quantity of matter in that direction, or its greater proximity; and gravitation is the approximating movement which such a preponderance creates.

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* The above estimate supposes these bodies to have no rotation. It has been calculated that Jupiter's rotation would diminish the weight of a body at its equator about one-ninth part.

From the preceding observations it is obvious, that the characteristic distinction of ponderable and imponderable bodies, consists in the exclusive possession of an inherent repulsive force by the latter towards matter of its own kind; and hence also the extreme, or probably, perhaps, the infinite division, and the inconfinable nature of the imponderable bodies. At the centre of the earth, matter which would be ponderable in all other situations, becomes as incapable of being weighed as any of the imponderable substances. At the earth's surface, (where only it is in our power to subject bodies to the operation of weighing,) ponderable materials are more attracted towards its centre, than in any other direction, for the reason already mentioned; and hence their weight. But the imponderable bodies, in consequence of being actuated by an inherent repulsive force towards imponderable matter, as well as an attractive force towards ponderable substances, are enabled to penetrate, intermix with, and distribute themselves amongst the ponderable materials of which the earth, and all other celestial orbs, are composed, in such proportions, as every where (with but slight oscillatory variations hereafter to be explained) to maintain their equilibrium; and this equilibrium constitutes their imponderable character.

Atmospheric pressure, or rather, (for it applies to all matter as well as air,) the pressure of external matter towards the centre of the sphere to which it belongs, is another force, which, from its influence in modifying the relative distribution of ponderable and imponderable materials, requires to be noticed. The aggregate attractive influence of matter being greatest in a direct line from the surface to the centre of every sphere, it follows, that an interior stratum is subjected to the pressure, or weight, of all those that are exterior. And as bodies become more subject to the influence of this force, in proportion as their relative situation is farther from the surface, and nearer the centre of the sphere to which they belong, it may be inferred, that the density of matter must increase from the surface towards the centre of the earth; and for the same reason, from the surface towards the centre of all celestial orbs.

The truth of the preceding theoretical inference, has been demonstrated by the experiments of Dr. Maskelyne and Mr. Cavendish. From the experiments of the former of these philosophers, the mean density of the earth is 4.867, water being = 1. From the experiments of the latter, conducted upon principles less liable to error, the mean density of the earth is nearly 5.48, water being = 1. According to the latter of these estimates, the mean density of the earth may be reckoned rather more than double the mean density of the solid substances composing the crust of the earth, including all the materials from the surface to the greatest depth to which man has yet been able to penetrate.

Hence, both from theoretical inference and experimental results, it may be concluded, that in descending from the surface to the centre of the earth, the mean density of the concentric layers of ponderable matter, is gradually increased beyond what it would otherwise be, by the progressive augmentation of the superincumbent weight of external strata. And as the calorific capacity of bodies, estimated by weight, and the amount of caloric which they absolutely contain, are in all cases diminished by compression, and bear a general, though not a strict relation to their density, it may also be concluded, that in descending from the surface to the centre of the earth, the mean calorific capacity of terrestrial materials, and the amount of caloric which they contain relative to their affinity for it, undergo a diminution beyond what they would otherwise do, corresponding to the increase in their density, and arising from the same cause, viz. the progressive augmentation in the superincumbent weight of external strata.

But though the capacity of ponderable particles for holding caloric by attraction in immediate proximity to their surfaces is diminished by condensation, by whatever means effected, their attraction for it remains undiminished. Hence, the ponderable materials composing the more central and denser portions of the earth, in proportion as they are under-saturated with caloric, or in other words, in proportion as they are deprived of their due share of caloric, by condensation, must be exerting an unneutralized attractive force (which like every other, whether attractive or repulsive, is subject to the law of mass and distance) upon all caloric surrounding the surface of the earth, and contained within its crust. The consequence of this must be, that the amount of caloric surrounding the earth in the form of an atmosphere, and probably extending somewhat beyond the boundary of the aerial atmosphere; and also the amount intermixed with the superficial and less condensed solid terrestrial strata within the reach of human observation, will be increased beyond what these superficial strata would otherwise be able to retain by their own affinity for caloric.

From the preceding observations it may be inferred, that the existing distribution of the ponderable and imponderable materials of which the earth and other planetary bodies are composed, is the necessary result of the mutual action of the attractive and repulsive properties, originally and permanently conferred upon the various kinds of matter by the will of their Creator. Ponderable materials, by means of attraction subsisting between their particles, are concentrated into those aggregate revolving masses, which have been denominated suns, stars, satellites, and comets. Were attraction the only force existing in nature, the ponderable or mutually attractive materials of each of these celestial orbs, could only exist as solid, cohering, and incompressible masses; and the whole of them would ultimately concentrate into one. The imponderable materials, provided repulsion subsisting between their particles were the only force acting upon them, would distribute themselves equally throughout unoccupied space. But this force being counteracted by a strong attraction exerted upon them by ponderable materials, their equilibrium, and imponderable character, is every where maintained, by their being concentrated in the form of an atmosphere around the various celestial orbs, and intermixed with the concentric layers of the ponderable substances of which they are composed, in quantities proportioned to the degree of influence exerted upon them by the conjoint forces of attraction for ponderable materials, and repulsion subsisting between their own particles, modified by the compression of external strata of ponderable materials gravitating towards the centre of each sphere. The calorific atmosphere surrounding the earth probably extends considerably beyond the boundary of the aerial atmosphere. And as the central portions of the sun must, from the immense magnitude of that luminary, be greatly more condensed by the pressure of external strata gravitating towards its centre, than those of the earth, their capacity for caloric, and the amount they contain relative to their affinity for it, must be diminished to a much greater extent, than the corresponding central portions of the earth. Accordingly it may be inferred, that the calorific atmosphere surrounding the sun, and attached thereto by the unneutralized calorific attraction exerted upon it by the ponderable materials of its more condensed central portions, extends to a much greater distance around the solid surface of the sun, than that which surrounds the earth. In short, the calorific atmosphere surrounding planetary bodies should be more extended, and the amount of caloric intermixed with their superficial and less condensed strata, beyond what those strata would be able to retain by their own affinity for it, should be greater, according as the planetary body is larger; for increase of size, other things equal, supposes, that its central portions should be proportionally more condensed by the superincumbent weight of external strata of ponderable materials, and thereby deprived in a greater degree of their due share of caloric, while their affinity for it remains undiminished.

The intermediate space between one planetary body and another may be conceived to be an entire vacuity, because planetary motion can be most satisfactorily explained upon this supposition. This conception implies, that no interchange of heat, light, or other imponderable matter, ever takes place between different planetary systems; nor even between different celestial bodies belonging to the same system. The caloric, light, and electricity, attached to the earth by the attraction of its ponderable materials, are never transmitted to any other celestial body, but remain permanently attached to it during all its revolutionary movements. And in like manner, the heat and light held in attraction by the ponderable materials of the sun, are never transmitted to the earth, nor to any other celestial orb. The radiation of heat by the sun, therefore, consists neither in the transmission of calorific particles from that luminary to the earth, with the inconceivable velocity of about 195,000 miles in a second, as some have supposed; nor in a vibratory movement among the particles either of ponderable materials, or of those of caloric, capable of being excited by the sun or heated bodies, as others have imagined. In the subsequent paper expressly written on the radiation of caloric, I have endeavoured to refute the theories at present entertained on that subject, preparatory to introducing one of my own. It would be out of place here to introduce such a refutation, but as the solar radiation of heat is intimately connected with the views I entertain regarding the cause of planetary motion, it may not be amiss to submit the following brief abstract of the notion I entertain on that subject.

While the ponderable materials contained in the earth are attracted by those of the sun, I conceive that caloric and the other imponderable substances contained in the earth, and concentrated by attraction around it, are repelled by the caloric, and other imponderable materials, contained in, and concentrated by attraction around the sun. The solar radiation of heat, therefore, as experienced by man, whose place of observation is restricted to the bottom of the aerial and calorific ocean surrounding the globe, is neither more nor less than caloric descending slowly through the atmosphere, and penetrating the crust of the earth, produced by the repulsion of caloric, and other imponderable materials, contained in, and concentrated around, the sun. I conceive that radiant caloric never moves but with extremely little velocity in comparison with what is usually imagined; that the velocity of its motion varies with the strength of the impulse, and the degree of repulsive resistance it encounters; that where there is no resistance, the actual moving velocity of radiant caloric diminishes as the square of the distance from the source of motion increases. I farther conceive, that the commonly received notion of the radiation of caloric consisting in an inconceivably rapid projection of calorific particles from hot to cold bodies is erroneous; and that this inconceivable velocity, with which caloric has been hitherto supposed to travel by radiation, is merely a propagation of the preponderance of calorific repulsion, and in obedience thereto, a slow receding motion by all caloric exposed to the preponderating impulse.

The equilibrium of the calorific atmosphere* surrounding and permanently attached to the earth, is subjected to a constant cause of disturbance by the earth's diurnal rotation on its axis. Each portion of the earth's surface, during the alternations of day and night, and summer and winter, being successively more or less directly presented to, and turned away from the sun, is alternately absorbing, and giving out caloric. During day, the attraction exerted by the ponderable materials of the earth upon the atmosphere of caloric by which it is surrounded, being aided by the repulsion exerted towards terrestrial caloric by the calorific atmosphere surrounding the sun, preponderates over the forces which oppose the entrance of more caloric into the crust of the earth. And consequently, in obedience to the preponderance of pressure, and in order to the restoration of the calorific equilibrium, the side of the earth presented to the sun absorbs caloric. During night, when the attraction exerted by the ponderable materials of the earth, upon the surrounding atmosphere of caloric, ceases to be assisted by the repulsion of that which is concentrated around the sun; and when the amount of caloric contained in the earth is increased by the quantity absorbed during the previous day, the forces which tend to expel caloric from the earth's crust, preponderate over those which enable it to penetrate. And consequently, in order to the restoration of the calorific equilibrium, the earth, or to speak more precisely, the side of the earth turned away from the sun, gives out caloric. Such I conceive to be the nature and cause of the solar radiation of heat towards the earth, and of the rise of temperature around us, during day; and of the corresponding radiation of heat from the earth, and of the sinking of temperature around us, during night.

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* From the fact of caloric radiating from a fire, while the atmosphere, in order to support combustion, is flowing towards it, we infer, that only a portion of the caloric contained in the atmosphere is held in affinity by the aerial particles, while another portion is merely intermingled with the aerial particles, and not held in affinity by them. The movement of the former of these portions of caloric, is determined by that of the aerial particles by which it is held in affinity; while the movement of the latter, which is the only portion that radiates, is determined by the preponderance of calorific repulsion exerted upon it. The term calorific atmosphere, used in the above and other passages, includes not only caloric distributed around the earth at a greater altitude than the aerial atmosphere, but also that portion of caloric, which, though intermingled with the aerial particles, is free to move or radiate in obedience to the preponderance of calorific repulsion.

We will now proceed to explain in detail the various centrifugal movements exhibited by planetary bodies; and for this purpose will dwell principally upon those to which the globe we inhabit, and its attendant the moon, are subjected, as affording examples of all the movements exhibited by celestial bodies. And it need hardly be remarked, that the explanation of the centrifugal movements of the earth and moon are equally applicable, and may be extended by analogy, to those of all other celestial orbs.

SECTION VI.

ON THE CAUSE OF THE ROTATION OF THE GLOBE UPON ITS AXIS.

The first movement of the earth we mean to consider, is its rotation from west to east round an ideal line, extending between the north and south poles, called its axis. This rotatory revolution, which is performed in the course of 24 hours, gives rise to the succession of day and night, and all the phenomena attendant thereon. The nature of this movement is entirely centrifugal, and no attempt, so far as I am aware, has ever been made to explain its cause, save in the theory, which we have already endeavoured to refute, viz. that it arises from the gradual condensation of large quantities of widely diffused nebulous matter. It is obvious that the rotatory motion of planetary bodies is not produced by the mutual attraction of matter;

nor is it in any way a necessary result of the law of gravitation, as is proved by the fact, that the velocity of the rotatory movements of planets and satellites is neither directly proportional to the masses of the bodies round which their orbitual motions are performed, nor inversely proportional to the squares of their distances from them. Thus the earth takes 24 hours to perform a revolution on its axis; while Jupiter, at more than five times the earth's distance from the sun, takes only 9 hours, 55 minutes, 37 seconds; and Saturn, at more than 9½ times the earth's distance from the sun, takes only 10 hours, 16 minutes, and 2 seconds, to perform a similar revolution.

We have already endeavoured to prove, that the earth, and all other planetary bodies, are mere aggregations of ponderable and imponderable materials; and that, while the ponderable materials of these separate orbs are mutually attractive, their imponderable materials are mutually repellent. Now, suppose the earth divided into two hemispheres by a plane at right angles to the equator, and of course passing through both poles, which may be denominated a meridian section. If the hemisphere to the east of the meridian where the sun is vertical always contains the same relative proportions of ponderable and imponderable materials, and of course is equally attracted and repelled by the respective attractive and repellent materials contained in the sun, as the hemisphere to the west of the same meridian; it is obvious, that no rotation could possibly be generated by the attractive and repulsive forces inherent in the materials contained in the sun. But if it can be shown, as we shall endeavour to do, that the hemisphere of the earth that has passed the meridian, over which the sun is vertical, always contains around its surface a greater amount of caloric, and consequently is more strongly repelled by the caloric contained in and around the sun, than the other hemisphere, rotation is the necessary consequence.

From thermometric observations it appears, that, in the shade, the maximum diurnal atmospheric temperature within the tropics occurs about an hour after mid-day. Gradually as we advance from the tropics to higher latitudes, at least during summer, it becomes later in the afternoon; and in the latitude in which we live, it may be about three hours after mid-day. But in all latitudes, and seasons of the year, the minimum diurnal temperature takes place about an hour before sunrise. If we were, therefore, to estimate the amount of caloric in the different hemispheres of the earth, to the east and west of the meridian where the sun is vertical, by thermometers, we would have no difficulty in arriving at the conclusion, that the amount of caloric contained in the atmosphere, and in the superficial strata of the earth, is at all times greater in the hemisphere to the east of the meridian where the sun is vertical, than in that to the west of the same meridian. And as the former hemisphere is therefore more repelled by the caloric or other calorific repellent materials contained in and concentrated around the sun, than the latter, while it is equally attracted, we would immediately say, that the rotation of the earth was owing to that cause. In reality, as will subsequently appear, I believe the cause above assigned for the rotation of the earth to be the true one; and the adoption of the commonly received projectile theory of solar radiation, in so far as it would render farther explanations unnecessary, would here be exceedingly convenient. But when, in accordance with the theory of solar radiation which we have already briefly stated, we bear in mind that a certain amount of caloric, and of other imponderable materials, are permanently attached to the several planetary bodies, and carried along with them in all their revolutions, and that no interchange of caloric or of other imponderable matter ever takes place between them; it requires some reflection to be able to perceive, how the caloric surrounding the hemisphere of the earth to the east of the meridian where the sun is vertical, should be greater in amount than in that to the west.

It is proper here to premise, that if the theory of Solar Radiation which I have proposed be considered erroneous; or if the view, in accordance with that theory, now to be given of the manner in which a greater accumulation of caloric always exists in the hemisphere to the east of the meridian where the sun is vertical, than in that to the west, be unintelligible to any person, it is requested that he continue to adhere to the commonly received projectile theory of Solar Radiation. The explanation to be given of the cause of centrifugal force in planetary motion, is equally in harmony with the projectile theory, as with the one I have proposed. According to the projectile theory of Solar Radiation, calorific particles, as well as those of light, are projected from the sun in every direction with the velocity of about 195,000 miles in a second. The arrestment of a portion of these particles by the side of the earth presented to the sun, and their accumulation thereon, is supposed to be the cause of the rise of temperature experienced during day; and their retrocession or radiation from the earth with equal velocity during night, is considered the cause of the reduction of temperature which then takes place. Now, as the least accumulation of calorific particles on the earth's surface, agreeably to this theory, occurs about an hour before sunrise, when the greatest cold is experienced; and the greatest accumulation about three hours after mid-day, when the highest diurnal temperature is attained; it is obvious, that the amount of caloric contained in the superficial strata of the terrestrial hemisphere to the east of the meridian where the sun is vertical, is greater than in those to the west of the same meridian. And this is the only admission connected with solar radiation, which our views regarding the cause of centrifugal force in planetary motion require.

We will now endeavour to show, that the existence of a greater accumulation of caloric in the terrestrial hemisphere to the east of the meridian where the sun is vertical, than in that to the west of the same meridian, is equally in accordance with the theory of solar radiation, of which we have already given a brief outline, as with the projectile theory. To understand how this should be the case, it is necessary to bear in mind, that the calorific, like the aerial atmosphere, has a tendency to maintain a uniform, or a nearly uniform elevation around the earth's surface, in consequence of a distant unsatisfied attraction for caloric exerted upon it by the central portions of the earth, which, as before stated, from condensation, are under-saturated with caloric. And the principal departures from this uniformity in elevation, are owing to the periodic disturbances of the calorific equilibrium, produced by the unequal repellent force exerted upon it during day and night, and the different seasons of the year, by caloric, and other calorific repelling materials contained in, and concentrated by attraction around the sun. In order that our description of what may be denominated a tide in the calorific atmosphere surrounding the earth, may be freed from any perplexity arising from local or periodic causes, we shall suppose, that the earth's surface is wholly covered with water or with land, the power of which in absorbing and radiating caloric is everywhere the same. And we shall farther suppose, that the plane of the ecliptic, or sun's apparent path in the heavens, always corresponds with that of the terrestrial equator extended. Now, the most obvious effect of the repulsion of caloric surrounding the sun, upon that surrounding the side of the earth presented to that luminary, is compression. And as the earth revolves upon its axis, the circular path of greatest calorific compression on the earth's surface, will be that over which the sun passes vertically.

The period of the twenty-four hours when the greatest retrocession of caloric from the land, water, and atmosphere, composing the crust of the globe, takes place, must correspond with the coldest period, as tested by thermometers, viz. about one hour before sunrise. After this time, the repulsion exerted by the caloric around the sun, will cause a gradual sinking of the calorific strata around the side of the earth presented to that luminary; and a slow absorption of caloric by the land, water, and atmosphere, composing the earth's surface. In this sinking of the calorific strata, and the consequent intermixture of an additional quantity of caloric with the ponderable materials by which we are surrounded, the warming influence ascribed to solar radiation consists. Provided land and water absorbed caloric as fast as it was compressed by the sun's influence during day; and again gave it out as speedily as the calorific compression diminished in the afternoon, the meridian of greatest calorific compression, where the greatest amount of heat absorbed by the land and water composing the earth's surface had taken place, should be that over which the sun was immediately vertical. This, however, is not the fact. Land and water, (particularly the former,) absorb caloric much more slowly than it is transmitted to them through the atmosphere, in the form of radiation. And though the atmosphere, and the surface of land and water presented to the sun, may reach their maximum temperature between two and three hours after mid-day; still, as the strata immediately below the surface continue to derive heat from the superficial strata, it is probable, that land and water exposed to the sun do not cease to absorb caloric, till about four hours after mid-day.

The retrocession or radiation of caloric from the ponderable materials around us, must begin so soon as the sun has so far declined towards the west, that its calorific repelling influence, conjoined with the earth's attraction for caloric, is insufficient to counterbalance the repulsion of caloric contained in the interior of the earth, towards that at or near its surface, assisted by the mutual attraction of ponderable materials, which operate by compression in expelling caloric. Now, this retrocession of caloric may be supposed to commence, (and at first it will proceed only very slowly,) immediately after the land and water have ceased to absorb caloric, viz. about four hours after mid-day; and it will continue to go on till about an hour before sunrise, when the greatest cold is experienced. At this time the calorific atmosphere operated upon by the refracted influence of the sun's heat, reverses its moving direction, and again begins to be absorbed by the land, water, and atmosphere, composing the earth's surface, and so continues till about four o'clock in the afternoon, when its retrocession or radiation from the earth again commences; and so on.

From the preceding observations it is obvious, that the columns of the calorific atmosphere surrounding the earth, must be lowest in that meridian, where, in obedience to the previous continuance of the sun's calorific repelling influence, the greatest amount of caloric has been absorbed by the land and water composing the earth's surface, and which by solar time corresponds to four o'clock in the afternoon. According to the same principle, the columns of the calorific atmosphere surrounding the earth, must have reached their greatest elevation above the earth's surface, in that meridian, where the retrocession of caloric from the land and water, has continued, without interruption, for the longest period immediately previous, and which corresponds to the coldest period of night, viz. about an hour before sunrise. Beginning then at the meridian of greatest calorific compression on the earth's surface, which by solar time corresponds to four o'clock in the afternoon, the external boundary of the terrestrial calorific atmosphere, relative to the level of the sea, may be supposed to rise in an inclined plane for 195 degrees towards the east, which brings us to the meridian where the time of day is an hour before sunrise. From that meridian in the same direction eastward, the external boundary of the terrestrial calorific atmosphere relative to the level of the sea, may be supposed to sink in a very slightly inclined plane for 165 degrees, which again brings us to the meridian of greatest calorific compression, where the time of day is four o'clock in the afternoon.

It has been already stated, that the calorific atmosphere, when uninfluenced by the repulsion of solar caloric, has a tendency, in order to its equilibrium, to maintain a uniform, or nearly uniform elevation around the earth's surface. But as the retrocession of caloric from the ponderable materials on the earth's surface is too long after mid-day of beginning, and too slow in its progress, to compensate for the diminishing calorific repulsion exerted by the sun, as his rays fall on the earth's surface with increasing obliquity after mid-day; it is obvious, that a tide in the calorific atmosphere following the path of the sun from east to west, must be generated around the earth, in order to the more rapid restoration of the calorific equilibrium. Indeed, without the aid of a calorific tide following the path of the sun, it is impossible, agreeably to the theory of solar radiation which we have advanced, to show how the aggregate amount of caloric could ever be greater in one hemisphere of the earth, than in the other. But if we bear in mind, that the sun exerts an influence in depressing the calorific columns on the side of the earth presented to it, there is no difficulty in understanding, how a calorific tide moving westward in the form of a broadly extended wave, analogous to the tides in the ocean, should follow the path traced diurnally by the sun over the earth's surface. In reality, it is neither more nor less, than that a calorific tide should flow, not in the form of a current, but in that of a broadly extended undulation, from the most elevated towards the most depressed calorific columns. At the external boundary of caloric, such a westward moving tide must result from the increasing elevation of the calorific columns towards the east; and amongst the inferior calorific strata, from the lateral pressure of caloric in an eastward direction preponderating, in consequence of its greater amount, over that towards the west. And it need hardly be remarked, that the greater amount of caloric here spoken of, refers only to the portion existing in the form of an atmosphere, and which accordingly is free to move by radiation: for that which is absorbed by land and water, is for the time fixed, and can have no immediate influence in producing a calorific tide, moving in obedience to the preponderance of calorific repulsion.

About an hour before sunrise, when the greatest diurnal retrocession of caloric from the land, water, and atmosphere, has taken place, the amount of caloric, including both what is contained in the superficial strata of land and water, and above them in the form of an atmosphere, attains its minimum. From that time till the sun has reached its meridian altitude, no increase of caloric can take place.

During that period, the calorific atmosphere will merely be getting more compressed, and absorbed, by the land and water composing the crust of the earth. Very soon, however, after the sun has passed its meridian altitude, and its power in repelling caloric on the surface of the earth has begun to decline, which may be supposed to occur one or two hours after mid-day, the calorific tide flowing from the east, and following the path of the sun, in order to restore an equal elevation in the calorific columns then depressed by solar influence, will gradually give rise to accumulation of caloric.

It is impossible to ascertain the precise time when the greatest accumulation of caloric, in any meridian, will take place. But as very little caloric can have retroceded from the land and water by radiation till sunset, viz. six o'clock in the afternoon, and as it retrocedes rapidly for some time after sunset; six o'clock in the afternoon may be guessed at, as the period when the greatest amount of caloric exists in any given meridian, including both what is retained in the superficial strata of land and water composing the earth's surface, and what constitutes the calorific atmosphere by which the land and water is surrounded. Immediately subsequent to sunset, the retrocession from land and water of previously absorbed caloric, is more rapid than at any other period. This, of course, by speedily augmenting the amount of caloric existing in the form of an atmosphere, will increase the rapidity of the calorific tide towards the west, and in some degree counteract the rapidity of the tide flowing from an eastward direction towards those meridians. Owing to these circumstances, it is probable, that the amount of caloric in the different meridians, including both what is contained in the superficial strata of land and water, and in the calorific atmosphere above them, gradually diminishes from sunset till an hour before sunrise, when it again attains its minimum.

If we were to suppose, for the sake of analogical illustration, that the sun, instead of compressing and causing a slow absorption of caloric on the side of the earth presented to it, exerted a repulsive force towards the aerial atmosphere, so as to compress and cause a portion of it to be slowly absorbed by the land and water during day; and that this portion was again slowly given out during night; we would have no difficulty in perceiving, how an atmospheric tide should follow the path traced by the sun on the earth's surface from east to west. Very soon after the sun had passed its meridian altitude, and its power in repelling the aerial atmosphere on the surface of the earth had begun to decline, a tide in the aerial atmosphere following the path of the sun, in order to restore an equal elevation in the atmospheric columns then depressed, and partly absorbed by land and water, would gradually give rise to an accumulation of air on the side of the earth over which the sun had previously passed vertically. And if we were to include in the estimate, not only the amount of air existing in the form of an atmosphere, but that which was absorbed by the superficial strata of land and water, we could have no difficulty in arriving at the conclusion, that the hemisphere to the east of the meridian where the sun was vertical, must always contain a greater amount than that to the west.

From the preceding imperfect view of tides in the calorific atmosphere surrounding the earth, following the path of the sun, it is obvious, that the terrestrial hemisphere to the east of the meridian where the sun is vertical, must always contain a greater amount of caloric, including both what is absorbed by its superficial strata of land and water, and what exists around those strata in the form of an atmosphere, than what is simultaneously contained in the hemisphere to the west of the same meridian. Now, as the hemisphere containing the greatest amount of caloric, must be more strongly repelled by the caloric contained in and concentrated around the sun, than that which contains the least, it is obvious, that a rotatory motion of the earth upon its axis from west to east is the necessary consequence. And as the earth, in accordance therewith, does revolve from west to east, it is reasonable to conclude, in the absence of any other explanation, that the earth's rotation is caused in the manner now described.

The rotation of all the other planets in the solar system, so far as yet ascertained, being performed in the same direction as that of the earth, viz. from west to east, it is probable, judging from analogy, that the equilibrium of their respective hemispheres to the east and west of the meridian where the sun is immediately vertical, is also subjected to a similar cause of disturbance. Hence it may be inferred, that the cause above assigned for the maintenance of the rotatory motion of the earth on its axis, is equally applicable to the rotation of all the other planets in the solar system.

SECTION VII.

ON THE ROTATION OF SATELLITES ON THEIR AXES.

The moon performs a revolution in an orbit round the earth, at the mean distance of 237,000 miles, in 27 days, 7 hours, 43 minutes, and 11 seconds, from any star to the same star again; and in 29 days, 17 hours, 44 minutes, and 3 seconds, from the sun to the sun again. As the moon always presents the same side to the earth, it is obvious that she takes exactly the same time to revolve round her axis, that she takes to revolve round the earth in her orbit. The former of the above stated periods is therefore the length of her sidereal day; and the latter the length of her solar day.

Notwithstanding the much greater length of time that the moon takes to revolve on its axis than the earth, it is obvious that it must be subjected to the same cause of rotation, viz. a greater amount of caloric simultaneously contained in, and around, the superficial strata of the lunar hemisphere, to the east of the meridian where the sun is vertical, than in those to the west of the same meridian. The circumstance, however, of its revolution and rotation being performed in equal times, leads to the inference, that there is some other counteracting and regulating force, which modifies the cause above assigned for its rotation, so as to produce the equality referred to.

The coincidence between the rotation and revolution of the moon, was ascribed by Newton to her having an oval form, one side of which was denser than the other. There is no doubt that the attraction of the earth will produce some slight influence in modifying the figure of the moon, and the density of her concentric strata of ponderable materials, seeing that the same side is constantly presented to the earth. But even though the moon were entirely spherical, and of equal density throughout, there is an obvious reason for her presenting always the same side to the earth. As the force of gravity diminishes as the square of the distance increases, it is evident that the attractive energy exerted by the earth upon the side of the moon which is nearest us, is stronger than that which is exerted upon the opposite side, in proportion to the difference in the squares of their distances. Now, I conceive that this stronger attraction is the cause which prevents the rotation of the moon on her axis being performed in shorter time, than she revolves round the earth in her orbit.

The following experiment will afford a satisfactory illustration of the influence of an attractive body, in preventing the rotation of another body, to which a rotatory impulse is applied. Suppose the edge of a steel wheel, supported upon a pivot, brought into apparent contact (for it is supposed impossible to bring separate bodies into absolute contact) with the pole of a powerful magnet, and pressure applied to it with the intention of producing rotation. In this case it will be found, that the wheel will not revolve, unless rotatory impulse be communicated so strongly, as to overcome both the friction of the pivot, and the attractive energy of the magnet. And it will farther be found, that the rotation of the wheel cannot be kept up without the continued application of a rotatory impulse, sufficient to overcome, not only the friction of the pivot, but the attractive energy of the magnet also. If the wheel be then visibly separated from the magnet, but still within the sphere of its attraction, it will now be found to revolve with a less degree of impulse communicated than it did before; but not so freely as it would do, provided the magnet was removed altogether. The influence of the magnet in counteracting the rotation of the wheel in the above experiment, is analogous to what is produced by the earth's attraction upon the moon. And if the distance of the moon's orbit from the earth could be gradually increased, a distance would at length be attained, where a similar cause to that which produces the earth's rotation, would at length overcome the counteractive resistance to the moon's rotation produced by the earth's attraction. At this distance, the moon's rotation, though very slow, would be performed in shorter time than she revolves round the earth in her orbit. And if the distance of the moon's orbit were still farther increased, the rapidity of her rotation would be thereby augmented, so that instead of revolving only once on her axis, she would revolve many times, during the period of her orbitual revolution round the earth.

It is a difficult matter to ascertain, whether bodies so small and distant as the satellites of Jupiter and Saturn, actually revolve on their axes. But from comparing the mutual positions of the satellites, with the times when they acquire their maximum of light, Sir William Herschel concluded, that, like our moon, they all turned round on their axes, in the same time that they performed their revolution round their primary planets. Admitting the truth of Sir William Herschel's conclusion, it may be inferred from analogy, that the cause assigned for the coincidence between the rotation and revolution of the moon, is also that which produces the similar coincidence between the rotation and revolution of the satellites of Jupiter and Saturn.

SECTION VIII.

ON THE CAUSE OF THE DIFFERENCE IN THE ROTATORY VELOCITY OF THE DIFFERENT PLANETS.

It may be asked, by way of objection to the hypothetical explanation advanced in the preceding Section, why the stronger attractive energy exerted by the moon upon the side of the earth which is nearest her, does not produce a reciprocal influence in causing the earth always to present the same side to the moon. I answer, 1*st*, Because the rotatory momentum of the earth is greater than that of the moon, in proportion to the superiority of its mass; and, 2*d*, Because the attractive energy exerted by the earth upon the moon, is greater than that which the moon exerts upon the earth, also in proportion to the difference in the masses of matter they severally contain. Hence the reason that the earth is enabled to arrest the rotation of the moon, while the moon is not able to arrest that of the earth. But though the attractive force exerted by the moon upon the earth, may not be sufficiently powerful to counterbalance that which produces the earth's rotation, still, analogously to the influence of the magnet, in retarding the rotation of the steel wheel when visibly separated from it, I am inclined to think, that the moon's attraction has some influence in retarding the velocity of the earth's rotation.

If the cause assigned for the equality in the periods the moon takes to revolve on its axis and in its orbit be correct, it follows, agreeably to the same principle extended, that the rotation of the primary planets during their revolutions round the sun, should be retarded (though in a much less degree, in consequence of being infinitely more distant) by the attraction exerted by that luminary on their sides which are presented to it being greater, than upon those which are turned away. The degree of retardation which the rotation of different planets will experience from the cause now under consideration, and the actual velocities of their rotation, will depend upon a variety of modifying circumstances, the absolute, or relative influence of which, separately or conjointly, it is impossible to determine. We will here, therefore, only point out their general tendency. 1*st.* The principal of these modifying circumstances is difference of distance from the sun. The more distant any planet's orbit is from the sun, other things equal, the less influence will the sun's attraction have in retarding its rotation on its axis; and *vice versa.* 2*d.* Other things equal, the smaller any planet is, the less will be the difference between the amounts of attractive force exerted by the sun upon the side presented to it, and upon that which is turned away from it; and of course, the less the influence of the sun's attraction in retarding the rotation of the planet; and *vice versa.* 3*d.* The larger any planet is, the greater ought to be the pressure of external strata gravitating towards the centre upon those that are interior. And as the capacity of bodies for caloric, and the amount they absolutely contain at any given temperature, is diminished by compression, while their affinity for it is not thereby lessened, it follows, that the larger any planet is, other things equal, the greater ought to be the amount of caloric contained in, and by attraction concentrated in the form of an atmosphere around its superficial, and less condensed strata. Now, as the rotation of planetary bodies depends upon unequal proportions of caloric, being simultaneously distributed over the surfaces of their hemispheres to the east and west of the meridian, where the sun is at any time vertical; and as that will in some degree depend upon the amount of caloric existing in the form of an atmosphere around planets; it follows, other things equal, that the larger any planet is, the more rapid ought to be its rotation on its axis; and *vice versa*. *4th.* The more the rotation of a planet is retarded by the attraction of satellites, the slower, other things equal, ought it to be. And satellites will have more influence in retarding the rotation of planets, according as their orbits are less distant from their primary planets; and in proportion as the inferiority in their masses, relative to that of their primary planets, is less. *5th.* The less dense any planet is, provided the inferiority in density results from a greater attraction and capacity for caloric, and from its being composed of a proportionally greater amount of caloric, relative to the amount of ponderable matter, the more rapid, other things equal, ought to be its rotatory velocity; and *vice versa.*

If the modifying influence of the preceding circumstances be considered, our theory relative to the cause of the rotation of planetary bodies, besides affording a plausible explanation of the otherwise inexplicable fact, of planets in general revolving more rapidly on their axes according as they revolve more slowly in their orbits, is in harmony with the actual phenomena presented to observation, as may be seen by an inspection of the following Table:

Names of the Planets.	Mean Diameter in English Miles.	Mean Distances from the Sun in round numbers of Miles.	Densities, that of Water being 1.	Proportional Quantities of Matter.	Diurnal Rotation Round their Axes.				Tropical Revolutions.				Sidereal Revolutions.			
					D.	H.	M.	S	D.	H	M.	S.	D.	H.	M.	S.
The Sun, .	883,246		$1\frac{2}{15}$	333,928·	25	14	8	0								
Mercury, . .	3,224	37,000,000	$9\frac{1}{8}$	0·1654	24	5	28	28	87	23	14	32·7	87	23	15	43·6
Venus, . .	7,687	68,000,000	$5\frac{11}{15}$	0·8899	0	23	20	54	224	16	41	27·5	224	16	49	10·6
The Earth, .	7,911·73	95,000,000	$4\frac{1}{2}$	1·	1	0	0	0	365	5	48	49	365	6	9	12
The Moon, .	2,180	95,000,000	$5\frac{1}{2}$	0·0225	29	17	44	3								
Mars, . . .	4,189	144,000,000	$3\frac{2}{7}$	0·0875	1	0	39	22	686	22	18	27·4	686	23	30	35·6
Ceres, . .	163 or 1,024	263,000,000	2						1,681	12	9	0				
Pallas, . .	80 or 2,099	265,000,000	2										1,703	16	48	0
Juno, . . .	1,425	252,000,000			1	3	probably		1,588	0	0	0				
Vesta, . .	238	225,000,000							1,155	4	0	0				
Jupiter, . .	89,170	490,000,000	$1\frac{1}{24}$	312·1	0	9	55	37	4,330	14	39	2	4,332	14	27	10·8
Saturn, . .	79,042	900,000,000	$0\frac{11}{32}$	97·76	0	10	16	2	10,746	19	16	15·5	10,759	1	51	11·2
Georgium Sidus,	35,112	1,800,000,000	$0\frac{22}{100}$	16·84					30,637	4	0	0	30,737	18	0	0

From the preceding Table it appears, that, of all the planets, Mercury, which moves more rapidly in its orbit through space than any of the others, has, in accordance with the hypothesis we have above advanced, by far the slowest rotation on its axis. Venus turns round on its axis in 39 minutes, 6 seconds, less time than the earth. But the earth having a moon attached to it, has, agreeably to our theory, the velocity of its rotation thereby diminished; for otherwise, it ought to revolve on its axis in less time than Venus. The rotation of Mars is also a shade slower than that of the earth. This probably is owing to its inferiority in size, as stated under the third modifying circumstance. A similar observation applies to the comparative slowness with which Juno, so far as ascertained, appears to revolve on its axis. Jupiter and Saturn, on the contrary, which are the two largest planets, and move more slowly through space in their orbits than any of those that are nearer the sun, have, in accordance with our theory, the most rapid rotation. The ring, and the greater number of satellites attached to Saturn than what are attached to Jupiter, and the greater counteractive resistance to rotation thereby produced, is probably the cause why Saturn revolves on its axis a slight degree more slowly than Jupiter. And the reason why the satellites of Jupiter and Saturn have not more influence in retarding their rotation, is probably the smallness of their mass relative to that of the primary planets. Thus, the mass of the earth compared to that of the moon, is only as 40 to 1; whereas, according to the estimate of La Place, the mass of Jupiter compared to that of his four satellites put together, is as 6183 to 1.

I am not aware that any hypothesis has ever been previously advanced with a view to explain the fact, so different from what might have been anticipated, of planets, in general, revolving on their axes with greater rapidity, according as their motion through space in their orbits is slower. And the circumstance of the hypothesis, now adduced, relative to the sun's attraction in retarding the rotatory velocity of the planets; and in like manner, relative to the mutual influence of planets and satellites in retarding the rotation of each other, affording, in connection with the previously stated modifying influences, a plausible, though a somewhat vague, explanation of that otherwise inexplicable fact, is some evidence of its truth.

If the rotation of the earth be owing to the cause we have assigned for it, viz. to a greater amount of caloric being simultaneously contained in, and concentrated around, the superficial strata of the hemisphere to the east of the meridian where the sun is vertical, than in that to the west of the same meridian; it is evident, that as that force is constantly acting, the rotation of the earth should continually increase in velocity, were it not for the counteractive resistance produced by the attraction of the sun and moon. On the other hand, if the attraction of the sun and moon has any influence in retarding the earth's rotation, analogous to the attraction of the magnet upon the steel wheel subjected to a rotatory impulse; it is obvious, that were it not for the unceasing stronger repelling influence exerted by the sun upon the hemisphere to the east of the meridian where the sun is vertical, than on that to the west, the earth's rotatory velocity would gradually diminish, till it ceased altogether. The existing rotatory velocity of the earth may, therefore, be considered the equilibrium resulting from the conjoint influence of a constant rotatory impulse, and an equally constant counteractive resistance thereto. And as these opposing forces will undergo an equal diminution, while the earth, moving in a slightly eccentric orbit, recedes from the sun; and an equal increase, when it again approaches that luminary; the rotatory velocity with which the earth at present revolves on its axis, may be regarded as that which it naturally acquires under existing influences exerted for an indefinite length of time; and which, without variation, it will for ever continue to maintain.

SECTION IX.

ON THE CAUSE OF THE CENTRIFUGAL VELOCITY OF PLANETARY BODIES WHILE REVOLVING IN THEIR ORBITS ROUND THE SUN.

It might be supposed, that to maintain the earth in its orbit without either approaching or receding from the sun, the repellent forces subsisting between the mutually repulsive materials contained in the earth and the sun, ought to be exactly equal to the attractive forces mutually subsisting between their respective component materials. To show that such a supposition is erroneous, it may be stated, that provided the earth had no orbitual movement round the sun, or in other words, provided the sun and earth in reference to each other were stationary, it is obvious, that to prevent the earth approaching or receding from the sun, the attractive and repellent forces exerted by the sun towards the earth would require to be exactly equal. But supposing a lateral progressive movement communicated to the earth at right angles to the direction of the sun from the earth, it is evident, that if the attractive and repulsive forces mutually subsisting between the sun and earth were equal, the earth, instead of revolving round the sun in a circular orbit, would recede from that luminary for ever afterwards, in the direction in which the lateral progressive movement was communicated. It is obvious, therefore, that the maintenance of the orbitual revolutions of planetary bodies round the sun, requires that the attractive forces exerted towards them by the sun, should preponderate over the repulsive. And the smaller the orbit, the greater is the amount of attractive preponderance required to prevent the planet from flying off from the sun.

We have already stated that the earth and all planetary bodies are mere aggregations of ponderable and imponderable materials; and that these several kinds of matter are at all times, and at all distances, exerting their mutually attractive, or mutually repellent properties. If we bear in mind that all bodies around us, even the simplest that can be subjected to examination, are compounds of ponderable and imponderable materials, it is obvious, that the quality of weight, or the tendency to gravitate towards the centre of the earth, which they present, demonstrates that the attractive forces exerted upon them by the materials of which the earth is composed, preponderate over the repulsive. In like manner, the increasing velocity with which planetary bodies move in their elliptical orbits while approaching the sun; and their diminishing velocity while receding from it, demonstrate, that the attractive forces exerted by the materials of which the sun is composed, upon those of the different planetary bodies of the solar system, preponderate over the repulsive. All the influences therefore produced on planetary motion, which have been hitherto ascribed exclusively to their mutual attraction, or mutual gravitation, should be attributed, according to our theory, to the preponderance of the attractive forces over the repulsive, which the sun and all planetary bodies, as aggregations of ponderable and imponderable materials, are at all times mutually, and simultaneously, exerting towards each other. Our object, therefore, in this Section, is to point out how a lateral progressive movement is communicated to the earth, so as to balance the preponderance of the attractive over the repulsive forces exerted by the sun towards the earth. And we must here remind those who are averse to receive any new theory, for no better reason than that it is new, that no astronomical calculation is in the slightest degree affected, by the alteration in our notions, regarding the nature and cause of planetary movements, we are about to propose. And we will thereby get rid of a scientific absurdity, which is never a true representation of nature, viz. that centrifugal force and motion has been communicated to planetary bodies in endless variety, without the agency of any material or physical cause.

In treating of the rotation of the earth upon its axis, we attempted to show that the hemisphere to the east of the meridian where the sun is vertical, contains in and around its superficial strata, a greater amount of caloric, than the hemisphere to the west of the same meridian, and that this occasions the rotation of the earth on its axis. Now, I conceive that the same cause which produces the rotation of the earth on its axis, is the principal agent in giving rise to the centrifugal force, which, with the aid of the centripetal, causes the earth to revolve perpetually in an elliptical orbit round the sun. The greater amount of caloric contained in, and concentrated around, the surface of the terrestrial hemisphere to the east of the meridian where the sun is vertical, than in that to the west of the same meridian, must necessarily cause the centre of terrestrial repulsion, (that is, the centre of the materials contained in the earth that are repelled by similar materials in the sun,) to be somewhat to the east of the earth's centre of gravity. If the centres of terrestrial gravity and repulsion at all times occupied the same identical position within the earth, the preponderance of the attractive forces over the repulsive, would cause the earth to fall directly towards the sun, more slowly, but in other respects, just as if there had been no repulsive force whatever. Now, supposing the attractive forces subsisting between the sun and earth were to cease, the circumstance of the earth's centre of repulsion being always somewhat to the east of its centre of gravity, would cause the repellent materials contained in the sun, to drive off the earth, not in a direct line away from the sun, but in a line somewhat inclined towards the west of that direction. Hence it is obvious, that the conjoint action of the attractive and repellent forces, must necessarily give rise to a progressive motion of the earth in an orbit round the sun; and the hemisphere to the west of the meridian where the sun is vertical being least heated, and consequently least repelled by the calorific repellent materials contained in the sun, must be that which proceeds foremost in the orbit.

The hypothesis above advanced in order to account for the centrifugal velocity of planets in their orbits, is supported by the evidence of being in strict accordance with the actual phenomena.

The terrestrial hemisphere to the west of the meridian where the sun is vertical, and which is least heated, and least repelled by the calorific repellent materials contained in the sun, is in accordance with our theory, always the foremost in the orbit. And this is the case not only with the earth, but with all the other planetary bodies in the solar system. With all of them, the hemisphere whose foremost boundary line in the diurnal rotation of the planet has just reached the meridian where the sun is vertical, is always foremost in the orbitual movement.

SECTION X.

ON THE CAUSE OF THE CENTRIFUGAL VELOCITY OF SATELLITES WHILE REVOLVING ROUND THEIR PRIMARY PLANETS, &c.

Though the circumstance of the hemisphere of the moon to the east of the meridian where the sun is vertical being always more heated than that to the west, may account for the moon's annual revolution round the sun, it will by no means account for the revolution of the moon round the earth. If the moon revolved on its own axis from west to east with as great rapidity as the earth does, the moon's revolution in its orbit round the earth, would have admitted of an explanation similar to that which we have given of the earth's revolution round the sun. But the equality in the times which the moon takes to revolve on its axis, and in its orbit round the earth, and the consequent perpetual presentation of the same side to the earth, demonstrates that the explanation we have given of the revolution of the earth in its orbit round the sun, is totally inapplicable to the revolution of the moon round the earth. We now come, therefore, to look out for some other cause of the moon's revolution in her orbit round the earth.

After reflecting on this point, I can perceive no cause in the slightest degree calculated to produce the effect, except the influence of the earth's attraction in communicating a portion of its rotatory velocity to the moon; and in the absence of any other plausible explanation of the phenomenon, I am inclined to think that this is the true one. The sides of the earth and moon which are nearest each other being mutually more strongly attracted, and thereby rendered as it were heavier, relative to each other, than those which are most distant, the attractive energy subsisting between the two bodies, may be considered analogous to a slight degree of cohesion, or adhesion, existing between them. And if it be admitted that the stronger attraction exerted by the earth, and the increased weight thereby produced, upon the side of the moon which is nearest us, has sufficient influence, in opposition to an unknown amount of rotatory impulse, to arrest the rotation of the moon, so as to make her present always the same side to the earth; it is reasonable to infer, that a portion of the earth's rotatory velocity should be communicated to the moon by the same force. Now, let us see whether this theoretical inference, relative to the cause of the centrifugal velocity of the moon while revolving in her orbit round the earth, be in harmony with the actual phenomena presented to observation.

1*st.* The moon revolves in her orbit round the earth in the same direction as the earth revolves on its axis, viz. from west to east. This is exactly what should exist on the supposition, that the revolution of the moon in her orbit is produced in the manner we have supposed. It is true, that during the earth's rotation, though the terrestrial hemisphere presented to the moon be moving in the same direction as the moon is revolving in her monthly orbit, the hemisphere of the earth which is turned away from the moon, is simultaneously moving in the opposite direction. But then be it recollected, that attractive and repulsive influences exerted by one body upon another, diminish as the square of the distance between them increases; and accordingly, the attractive influence exerted by the terrestrial hemisphere nearest the moon, must be stronger than what is exerted by that which is most distant. In short, the centrifugal velocity of the moon exhibited by her orbitual revolution round the earth, is produced by the conjoint influence of the earth's rotation, and the preponderance of attraction exerted by the terrestrial hemisphere presented to, and nearest the moon, over that which is turned away, and accordingly most distant from it.

2*d*. The earth's diurnal rotation is performed in 24 hours, whereas the moon takes 27 days, 7 hours, 43 minutes, and 11 seconds, to complete her revolution round the earth, from any star to the same star again; so that the earth turns round its axis 27 times, for once that the moon revolves round the earth in her orbit. Now, this disproportion in the periods of the earth's diurnal rotation, and the moon's revolution in her orbit, also accords with our hypothesis. Had absolute adhesion subsisted between the earth and moon, the moon would have revolved round the earth in 24 hours; whereas the continued rotation of the earth, whose attractive influence upon the moon has been compared in our hypothesis to a slight degree of adhesion, only communicates a 27th part of that velocity.

3*d*. The satellites of Jupiter and Saturn, also revolve in their orbits in the same direction as their primary planets turn round on their axes; and the periodic time of the nearest satellite attached to either of those planets, is much longer than the period the primary planet itself takes to turn round its axis. Now, on the supposition that the orbitual revolutions of the satellites of Jupiter and Saturn, are produced in the same manner as that of the moon, the analogies above pointed out also corroborate our hypothesis. On the other hand it may be said, that the satellites of the Georgium Sidus revolve round their primary planet in a retrograde direction to that of the moon, and all other satellites. We will subsequently advert to this fact.

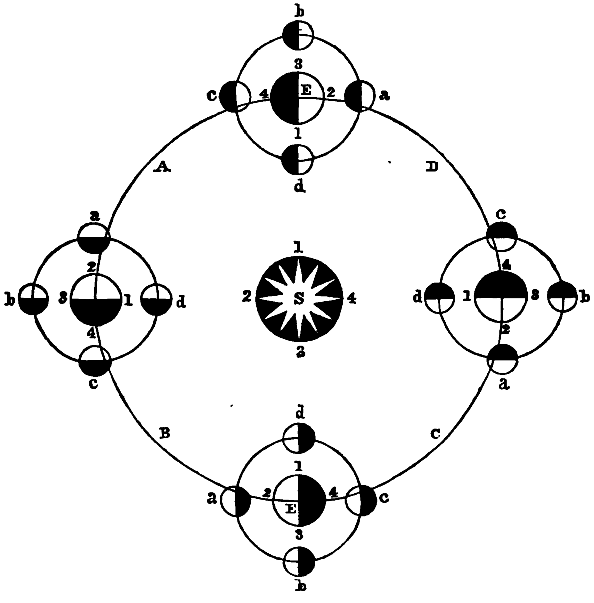
In the meantime it may be stated, that the direction in which the Georgium Sidus itself revolves on its axis, or whether it performs a rotatory revolution at all, has never been determined by any observations that can be relied on. That the satellites of that distant planet perform their orbitual revolutions in an opposite direction to that in which their primary planet revolves on its axis, is therefore only an inference, and ought not to be reasoned upon as if it had been an ascertained fact. Setting aside, therefore, the case of the satellites of the Georgium Sidus for subsequent consideration, it must be admitted, that the actual phenomena presented by the revolutions of the moon and other satellites in orbits round their primary planets, accord with, and therefore so far confirm, the theoretical inference we deduced in order to explain their cause.

The influence of the rotation of the earth, and of other primary planets, in producing the centrifugal velocity which causes the moon, and other satellites, to revolve round their primary planets, I conceive might be illustrated analogically, and the truth of our hypothesis thereby so far confirmed, by means of any mechanical contrivance, such as the following.

Let a powerful cylindrical magnet be suspended perpendicularly, so that its lower pole is on a level with a surface of water; and let the lower end of the magnet be surrounded by a thin glass tube or covering, so as to separate it entirely from the water. The glass tube should be nearly in contact with, but not absolutely touching the magnet; and it ought to be fixed so as not to move when the magnet within it is turned round. Let a light steel wheel supported above the surface of the water, by its pivot being inserted in a piece of floating cork, or other light substance, be then placed outside of the glass tube, and its edge brought into contact therewith, so as to be within the sphere of the magnet's attraction. I conceive that if the cylindrical magnet be then turned rapidly round its axis, it will cause the steel wheel to revolve slowly round the outside of the stationary glass tube that separates it from the magnet, in the same direction as the magnet is revolving; and in fact, will exhibit a representation of the manner in which the moon, and other satellites, are made to revolve round their primary planets.

If the rotation of the primary planets on their axes, be the cause of the centrifugal velocity, which occasions the revolution of satellites round them in the same direction, it may be inferred, that the sun's rotation on its axis, notwithstanding his great distance from the planets, has some slight influence in assisting the cause we previously assigned for the revolution of planetary bodies in their orbits round him. The arguments in support of this inference need not be repeated, as they are the same as those just advanced in support of the hypothesis, that the earth's rotation is the cause of the centrifugal velocity of the moon in her monthly orbit. And the fact of all the planets and satellites in the solar system, revolving in their orbits round the sun, in the same direction as the sun revolves on its axis; and the other fact of Mercury, the nearest planet to the sun, taking a much longer time to perform its orbitual revolution, than the sun takes to turn round its axis, accord with, and therefore so far confirm the inference.

In the annexed wood-cut, the relative movement of the sun, earth, and moon, are represented.



S is the sun, and E the earth, revolving on their axes from west to east in the direction 1, 2, 3, 4. The moon is represented moving round the earth in its monthly orbit *a*, *b*, *c*, *d*, which is in the same direction as the earth turns on its axis. And the earth, accompanied by its attendant the moon, is represented revolving in its annual orbit, A, B, C, D, round the sun, also in the same direction as the sun turns on its axis.

The earth and moon, as represented, are severally divided into two hemispheres by a plane corresponding to the meridian where the sun is immediately vertical, and which we formerly denominated a meridian section. The hemisphere represented white, is considered, from having previously been exposed to the sun's influence, to be the warmer, and therefore the more strongly repelled, of the two. Hence the cause of the earth's revolving on its axis in the direction 1, 2, 3, 4. And though, for reasons already mentioned, the moon only revolves once on its axis in the time it takes to revolve round the earth in its orbit, by recollecting that the letters *a*, *b*, *c*, *d*, are placed over the same identical points of the moon's surface, it may easily be perceived, that the moon revolves on its axis in the same direction as the earth. The blackened hemisphere, whose foremost boundary line, in the rotation both of the earth and moon, coincides with the meridian where the sun is vertical, is considered the colder of the two, and therefore is less repelled than the other by the calorific repellent materials contained in, and concentrated around the sun. And it will be observed, that the less repelled hemisphere, both of the earth and moon, always proceeds foremost in their annual orbit. All the other planets, so far as yet ascertained, revolve on their axes, and in their orbits, in the same direction as the earth. Those that are called inferior planets, move in circles interior to that of the earth; and those denominated superior, in circles exterior to that of the earth.

It will also be perceived, that while a spectator on the earth's surface at fig. 1, which corresponds to mid-day, is carried eastward by the earth's rotation, he is at the same time carried in the opposite direction, by the earth's annual revolution round the sun. At fig. 3, however, which corresponds to midnight, he is simultaneously carried in the same direction, both by the earth's diurnal rotation, and by its annual orbitual revolution.

SECTION XI.

THE MONTHLY ORBITUAL REVOLUTION OF THE EARTH AND MOON CONSIDERED IN RELATION TO THEIR ANNUAL REVOLUTION ROUND THE SUN, WITH AN EXPLANATION OF THE CAUSE OF THE EARTH'S MONTHLY REVOLUTION.

In consequence of the velocity of the moon in her diurnal orbit round the sun, being so much more rapid than that in her orbit round the earth; the orbitual motion of the moon round the earth, if viewed from the sun, will present no other appearance than that of constant progression with unequal degrees of velocity. During one half of each lunation, she will appear to move more rapidly than the earth, and during the other half more slowly. From the first quarter, when she is farthest behind the earth, to her third quarter, when she is farthest a-head of the earth in their annual orbit round the sun, the moon will appear to move faster than the earth, by about 237,000 miles each quarter, which is equivalent to the mean distance of the moon from the earth. And from the third to the first quarter, she will appear to move at a similar rate more slowly than the earth. As the preponderance of the attractive over the repulsive forces mutually subsists between all planetary bodies, the earth, if viewed from the sun, will also appear to be moving with unequal velocity in its annual orbit. During the half of each lunation that the earth in its annual orbit is behind the moon, the motion of the earth in its orbit will appear a very slight degree more rapid than average, in consequence of being then accelerated by the moon's attraction; whereas, during the other half of each lunation, when the earth is a-head of the moon, the progressive motion of the earth in its annual orbit will be rather slower than average, in consequence of being then retarded by the moon's attraction.

If the earth had no satellite, the orbit it describes round the sun would be a perfect ellipse. In consequence, however, of being attended and attracted by the moon, the actual path traced by the earth's centre, in its revolution round the sun, deviates in an extremely slight degree from a perfect ellipse, into an undulated elliptical curve, somewhat approaching to serpentine. During the half of each lunation that the moon is external to the elliptical orbit, which the earth would describe if there was no moon, the earth's centre, in consequence of the moon's attraction, is also external to it; and during the half of each lunation that the moon is internal to the perfect ellipse, the earth's centre, in consequence of the moon's attraction, is also within it.

The path traced by the moon through space, and resulting from the conjoint influence of its monthly revolution round the earth, and its yearly orbitual movement round the sun, is also an ellipse, the curve being greatly more undulated, and approximating much more to a serpentine curved line, than that which the earth describes. But the degree in which even the moon's actual path in the heavens deviates from a perfect ellipse, is so exceedingly trifling, that when represented strictly as it is, on any moderate scale on paper, the undulations of the line are not visible to the eye. This effect results from the moon's motion in her orbit round the sun, being about 30 times more rapid than that in her orbit round the earth. Her mean velocity in her orbit round the earth is only about 2290 miles an hour; whereas, her mean velocity in her orbit round the sun, is 68,080 miles in the same time. The consequence of this extreme disparity in her moving velocity in her different orbits, is, that the actual path described in the heavens, during her compound orbitual movement, is not only constantly progressive, and never retrograde, but is always concave towards the sun.

If the monthly orbitual movements of the earth and moon be considered divested of their annual motion round the sun, they will be found to consist of two circles, an interior, and an exterior one, described around the same centre, which is the common centre of their orbits. While the moon describes the exterior circle in 27 days, 7 hours, 43 minutes, and 11 seconds, the earth describes in the same time the interior one; and the respective diameters of the circles are inversely proportional to the masses of the orbs that move in them, viz. about 40 to 1. Now, as the relative position of the earth and moon, in reference to the common centre of their orbits, is at all times on the same side of their respective orbits, it is obvious that this minor monthly revolution of the earth, is produced by the preponderance of the attractive over the repulsive forces, exerted by the ponderable and imponderable materials contained in the moon, upon those contained in the earth.

Thus we see, that while the rotation of the earth, acting in conjunction with the preponderance of attractive forces exerted by the earth upon the moon, produces the orbitual movement of the moon round the earth; the orbitual revolution of the moon round the earth, acting in conjunction with the preponderance of attractive forces exerted by the moon upon the earth, is the cause of the minor orbitual revolution of the earth round the common centre of the orbits described by the earth and moon. In short, rotation is the primary centrifugal movement which directly, or indirectly, produces every other. And that which we have pointed out as the cause of rotation, may be considered the moving power, which, acting in conjunction with the centripetal force, is calculated for ever to maintain and regulate, the direction, and velocity, of all planetary bodies, while revolving on their axes, and in their orbits.

SECTION XII.

ON THE ROTATION AND ORBITUAL REVOLUTION OF THE SUN.

THE rotation of the sun on its axis, may be considered the result of a similar cause to that which we assigned for the rotatory motion of the planets. As the sun performs a rotation on' its axis in much less time than even the nearest planet takes to revolve round him in its orbit, it seems probable from analogy, that the caloric contained in and concentrated around each planet, has an influence in causing a slightly greater accumulation of caloric in the solar meridians, over which each planet has been recently vertical, than in those which, in the sun's rotation, have not reached the point where the planet is vertical. Hence, the hemisphere of the sun over which any planet during the sun's rotation has just passed vertically, should be more strongly repelled by the planet, than that whose foremost boundary line has just reached the meridian where the planet is vertical.

The revolution of the different planets in their orbits, operating in conjunction with the stronger attraction which they exercise upon the side of the sun that is nearest them, would have some influence in communicating rotatory motion to the sun, provided that luminary had no rotatory motion otherwise, or one that was slower than the periodic times of the planets. But as the sun's rotation on its axis is performed in much shorter time than the period which even the nearest planet takes to revolve round him, the attraction of the planets will rather retard than accelerate the rotation of the sun. A similar observation is applicable to the influence of the orbitual revolution of the satellites, in rather retarding than accelerating the rotation of their primary planets.

As the sun contains above 600 times more matter than all the planets in the system put together, their influence upon it in producing an orbitual motion round the centre of gravity of the system, is exceedingly trifling. The attractive forces exerted by the different planets upon the sun preponderating over the repulsive; the orbitual movement of the sun, if it can be so called, is produced by the preponderating attraction of the planets, in the same manner as the monthly orbitual movement of the earth, which we have already explained, is produced by the attraction of the moon. There is this difference, however, between them. The orbitual movement of the sun, is the result of the preponderating attractive influence of a considerable number of planetary bodies, acting at different times more or less in conjunction with, or more or less in opposition to, each other; whereas, the monthly orbitual movement of the earth, is dependent upon the attraction of the moon alone. Hence the former of these orbitual revolutions is exceedingly complicated, and difficult to trace; whereas the latter is comparatively simple, and uniform.

SECTION XIII.

ON THE INCLINATION OF THE EARTH'S AXIS FROM A LINE PERPENDICULAR TO THE PLANE OF ITS ORBIT.

The earth in its annual revolution round the sun, has its axis constantly inclined 23½ degrees from a line perpendicular to the plane of its orbit. This inclination, which gives rise to the different seasons of the year, has been hitherto considered the result of fixity in the position of the earth's axis, dependent upon, and regulated by no material or physical cause. Instead of this being the case, I am inclined to think that it is the result of a slow oscillatory movement, annually performed by the earth relative to the position of the sun. And the circumstance of its being performed regularly and gradually, and taking the same time in completion that the earth takes to revolve round the sun, gives the earth's axis a fixed position in relation to the stars. If this oscillation of the earth's axis took either more or less time in completion, than the earth takes to revolve round the sun from any star to the same again, the direction in which the earth's axis points, would be continually shifting relative to the position of the stars. In reality this, though the progress be extremely slow, is actually taking place; so that there is no real fixity of the earth's axis in relation to the position of the stars. Owing to the earth's rotation, more matter is accumulated in the equatorial regions, than in higher latitudes. And the sun and moon, by attracting this excess of matter, bring the equator sooner under them at each return to it, than if there had been no such accumulation of matter. The consequence is, that the earth returns to the same equinox, or the same solstice, 20 minutes, 17½ seconds, of time sooner each year, than it completes its revolution round the sun from any star to the same again. Owing to this circumstance, the equinoctial points recede 50 seconds of a degree westward every year, contrary to the sun's annual progressive motion in the ecliptic. This is called the precession of the equinoxes; and it has the effect of causing the pole of the earth's axis extended into space, to describe a circle round the pole of the ecliptic as a centre, at the distance of 23° 28′ from it, in the lengthened period of 25,868 years.

This annual oscillation of the earth's axis relative to the position of the sun, I conceive is owing to the alternate greater accumulation of caloric in the northern and southern terrestrial hemispheres, as they become successively in the course of the earth's annual revolution presented to, and turned away from the sun. As the calorific materials contained in and concentrated around the sun, are constantly repelling the corresponding materials contained in and concentrated around the earth, it is obvious, that the northern and southern hemispheres of the earth will be unequally repelled by the sun, according as they become alternately unequally heated. The cause, therefore, of the slow oscillation of the earth's axis now under consideration, is the stronger repellent force exerted by the sun towards each hemisphere, as it alternately becomes warmer than the other. Or, if we consider the sun and earth as aggregations of ponderable and imponderable materials, whose mutually attractive properties preponderate over those that are mutually repulsive, the cause of the slow annually performed oscillation of the earth's axis, may be said to be, the stronger attractive force which the sun successively exerts towards the northern and southern hemispheres, as they alternately, during the earth's annual revolution, become colder than each other.

The difference in the temperature of the atmosphere, and of the superficial strata of the earth when tested by thermometers, affords satisfactory evidence, that the amount of caloric in the northern and southern hemispheres alternately increases, and diminishes, during their respective summers and winters. This is accomplished, agreeably to our theory of solar radiation, by means of a gradual transference of a portion of caloric from one hemisphere to the other. During summer, when the sun to northern latitudes is longer above the horizon than below it; and when his rays fall on the earth's surface more perpendicularly than average, the land, water, and atmosphere, composing the crust of the globe, absorb a larger amount of caloric during day, than they give out during night. On the contrary, during winter, when the circumstances above-mentioned in reference to the sun are reversed, the land, water, and atmosphere, composing the crust of the earth, under the compressing influence of attraction subsisting between their particles, give out a greater amount of caloric during night, than they absorb during day. A similar amount of caloric to that which is given out by the land and water in the one hemisphere, is simultaneously absorbed by the land and water in the other. And the transference of that similar amount of caloric from the one hemisphere to the other, is effected by the tendency of the calorific atmosphere, which exists intermingled with the aerial atmosphere, and probably extends to some considerable though unknown height above it, to maintain an equal, or a nearly equal elevation above the level of the sea all around the globe. If we were to suppose, for the sake of illustration, that instead of caloric, a portion of the aerial atmosphere was slowly absorbed by the land and water when the sun was above the horizon, and again slowly given out when that luminary was below it; and that the amount of atmosphere absorbed exceeded that given out during summer, as much as it fell short of it during winter; the gradual transference of a portion of the aerial atmosphere from the one hemisphere to the other, would be accomplished in a manner perfectly analogous, to that in which we conceive a portion of the calorific atmosphere is transferred.

Let us now suppose the earth arrived at that part of its orbit, which corresponds to the summer solstice, in the northern hemisphere. If it be admitted that caloric contained in and concentrated around the sun, repels caloric contained in and concentrated around the earth, it follows, that the northern hemisphere being then more heated, must be more strongly repelled by caloric and other calorific repellent materials contained in the sun, than the southern hemisphere. The consequence of this must be, that the earth, in the course of its farther annual revolution, will have its northern hemisphere gradually driven away from being presented to the sun. But as the motion of planetary bodies is the conjoint result of the preponderance of forces immediately acting upon them, and of their previously acquired moving velocities; the gradual turning away of the northern hemisphere from the sun, does not cease immediately upon the southern hemisphere becoming as warm as the northern, but continues till the superior warmth of the southern hemisphere, and the increasing repulsion exerted by the sun towards it, at length overcomes the acquired velocity. This takes place when the earth reaches the part of its orbit corresponding to our winter solstice. After that period, the southern hemisphere being more repelled by the sun than the northern, in like manner continues gradually to turn away from the sun, till the earth again reaches that part of its orbit which corresponds with our summer solstice. By this time, the acquired velocity of the southern hemisphere in turning away from the sun, is entirely overcome by the greater warmth of the northern, and the consequent stronger repulsion exerted towards it. And thus a similar repetition of causes and consequences to that now described, is for ever maintained.

The minor secular and periodic movements to which the earth is subjected, such as the nutation of its axis, and other mutual perturbations of the planets while revolving in their orbits, need not be here commented on. Our theory merely requires, that such movements as have hitherto been ascribed exclusively to the force of attraction, should be attributed to the preponderance of the attractive over the repulsive forces, which all planetary bodies mutually exert towards each other.

SECTION XIV.

ON THE DEVIATION OF THE ORBITS OF SATELLITES FROM THE PLANE OF THE EQUATOR OF THEIR PRIMARY PLANETS.

If the centrifugal velocity exhibited by the moon in her orbitual revolution round the earth, be owing to the communication of a portion of the earth's rotatory velocity, in the manner described in Section X., the same cause which produces this centrifugal velocity, should have some influence in making the moon adhere to an orbit coinciding with the plane of the earth's equator. The centrifugal velocity of rotation at the surface of every sphere, increases from its poles to its equator. By the motion of the earth on its axis, the inhabitants at the equator are carried 1042 miles every hour; while those residing on the parallel of London, are carried only about 580 miles in the same time. Now, if the orbitual centrifugal velocity of the moon be occasioned by the earth's rotation, the moon's orbit ought to have a tendency to coincide with the plane of the earth's equator; and were any cause of deviation to occur, should tend to return to it, for two reasons. 1*st.* Because the strongest centrifugal impulse must be communicated to the moon by the equatorial regions of the earth, in consequence of the rotatory centrifugal velocity of the earth being greatest at the equator. 2*d*. Because the earth's rotation should communicate orbitual velocity to the moon, in a plane coinciding with that in which it turns itself on its axis, and not in any oblique direction.

There is little difficulty in assigning a reason, for satellites, in general, revolving in planes so nearly coinciding with the equator of their primary planets, as they are observed to do; for strict adherence to such planes, except for counteractive circumstances, constitutes their natural orbits. The chief difficulty lies in accounting for the orbits of satellites deviating at all from the equatorial plane of their primary planets; and this is the point to which we are now to direct our attention.

The deviation of the moon's orbit from the plane of the earth's equator, may be partly attributed to the slow oscillatory movement annually performed by the earth's axis relative to the position of the sun, described in Section XIII.; and which is usually denominated the inclination of the earth's axis to its orbit. This oscillation of the earth's axis relative to the position of the sun, amounts to forty-seven degrees each half-year. But though the superior rotatory velocity of the equatorial regions of the earth, imparts a tendency to the moon to describe an orbit round the earth, coinciding with the plane of the earth's equator; still, this annually performed oscillation of the earth, can only be in part communicated to the moon, for the same reason that the earth only communicates a portion of its rotatory velocity to the moon. Hence one reason why the moon's orbit does not coincide with the plane of the earth's equator.

Again, though the plane of the moon's equator only deviates from that of the ecliptic by an angle of 1° 30′ 11″, still this small inclination, by causing the northern and southern hemispheres of the moon to be alternately more or less presented to, and turned away from the sun, within the limits of 3 degrees as the maximum oscillation during each lunation, will have some influence, though a slight one, in rendering its southern and northern hemispheres successively unequally heated, and consequently unequally repelled by the calorific repellent materials contained in the sun. Now, this unequal repulsion exerted successively towards the northern and southern lunar hemispheres, instead of communicating a slow monthly compensating oscillation of the moon's axis, which is prevented by the earth's attraction forcing the moon to present the same side always to the earth, must necessarily be spent in producing a deviation in the moon's orbit from the plane of the earth's equator. This, therefore, may be considered another reason for the deviation of the moon's orbit from the plane of the earth's equator; and though no other cause existed, would of itself in some degree produce that effect.

Again, the orbit described by the moon round the earth is inclined 5° 9′ to the plane of the ecliptic. Of course, upon the supposition that the plane of the earth's equator coincided with the ecliptic, the circumstance of the moon's deviating, successively during each lunation to the extent of 5° 9′ on each side of that plane, would necessarily render the sun's attraction in some degree effective in drawing the moon towards, or away from, that plane, according as the moon was nearer, or more distant from the sun, than the earth was. This, therefore, is a third cause of the deviation of the moon's orbit from the plane of the earth's equator.

Again, in consequence of the northern and southern hemispheres of the earth becoming alternately very unequally heated, during their respective summers and winters; these hemispheres, according as the moon, at different times, is more or less directly presented to, and turned away from them, must exert different degrees of repellent force towards the moon. As the moon, however, is compelled by the earth's attraction to present at all times the same side to the earth; this unequal repulsion exerted towards it by the earth, must be spent in producing corresponding deviations in the plane of the moon's orbit. These, and probably other causes, by their simultaneous and periodic influences, assisted by the acquired velocities which they conjointly communicate to the moon, are sufficient to show that the moon's orbit round the earth, though produced by the earth's rotation, should not coincide with the plane of the earth's equator.

Let us next inquire what should result from planets, such as Jupiter and Saturn, having severally a number of satellites revolving round them at different distances, and with different velocities. In such cases, provided the orbitual revolution of the satellites be occasioned by the rotation of the primary planets, it might be expected, other things equal, that the stronger attraction and centrifugal impulse exerted towards the satellites that were nearest, should cause their orbits to adhere most closely to the plane of the equator of their primary planet. Now, it appears that the orbits of Jupiter's nearest satellites, deviate least from the plane of the equator of their primary planet. And in the case of Saturn, the rotation of the ring, which must be under the influence of the rotation of the body of the planet, and is less distant than any of the satellites, seems to be performed in the exact plane of Saturn's equator. It also appears that the orbits of the six interior satellites, coincide very nearly with the plane of the ring, and the equator of the planet. On the contrary, the orbit of the seventh satellite, which is much farther distant from the primary planet than those of the others, and of course is less exclusively under the influence of its rotation, deviates considerably from the plane of Saturn's equator, and approaches nearer to coincidence with the ecliptic.

The orbits of the satellites of the Georgium Sidus are inclined about 78° 58′ to the ecliptic, and their motion seems to be retrograde. As neither the inclination of that planet's axis to its equator, nor to the ecliptic, has been ascertained; and as it is not known from observation in what direction it turns on its axis, or whether it does so at all; it would be premature to make any hypothetical remarks concerning the orbits of its satellites.

We may conclude this Section by remarking, that every variation in the relative proportion, and direction, of attractive and repulsive forces, exerted by one celestial body towards another, must always produce a corresponding effect in determining the velocity, and direction, of its movements. And when a variety of partly conflicting, and partly co-operative influences, are constantly, and simultaneously exerted, the resulting motion may be equally regular and uniform, as though it had been wholly occasioned by a single cause.

SECTION XV.

ON COMETS, AND THEIR ORBITUAL REVOLUTIONS ROUND THE SUN.

COMETS are a class of celestial bodies which appear only occasionally, and for short periods of time, in the heavens. The rapidity of their movements among the stars, their ever-varying and singular appearances, and particularly the immense apparent magnitude which some of them present, have not only attracted the attention, and excited the wonder and astonishment of mankind; but have even caused them to be regarded as objects of terror, and omens that foreboded impending calamities about to befal the human race.

Comets are found in every part of the heavens, and move in all possible directions. They exhibit no visible or defined disc, but shine with a pale hazy light. They are likewise frequently, but not always, accompanied with a tail or luminous train, sometimes of immense apparent magnitude, which, in respect to the head or nucleus of the comet, whether advancing towards or receding from its perihelion, is always turned away from the sun. The smaller comets, which frequently present no appearance of a tail, seem, when viewed through telescopes, to be only round or somewhat oval vaporous masses, more dense towards the centre. And from the fact of stars of the smallest magnitudes remaining distinctly visible, not only through their tail, but even when covered by what appears to be the densest portion of the substance of their head, it has been inferred, that comets have no distinct nucleus, or any thing entitled to the character of a solid body. A similar inference has been drawn from the fact of the larger comets which have presented the appearance of a nucleus, never exhibiting phases, though there can be no doubt that they shine by the reflected light of the sun.

The orbits in which comets revolve round the sun, so far as yet ascertained, are ellipses, which for the most part are exceedingly eccentric; but observation has hitherto been able to furnish only very imperfect evidence, that either the head, or any nucleus within the head of comets, is subjected to a rotatory motion round an axis. As the theory we have advanced to account for centrifugal force in planetary motion, requires us to admit that comets revolve on their axes, in order to account for their centrifugal velocity in their orbits; it is necessary to inquire how far the negative testimony of no rotation having been hitherto ascertained, is to be received as evidence that they do not actually revolve on their axes.

From the fact of a comet's tail being always turned away from the sun, it is obvious that the tail does not revolve round its head, or nucleus, unless it takes the same time to do so, that it takes to perform a revolution in its orbit. The only point of inquiry, therefore, is, whether the head, or rather, whether any nucleus within the apparent head of the comet, performs a rotatory motion. The first fact that appears to militate against the rotatory motion of comets, is, that the smaller of this class of bodies appear to be so destitute of a nucleus, when viewed through telescopes, that stars of the smallest magnitude remain distinctly visible, even though covered by what appears to be their densest portion. The evidence for the non-rotation of comets afforded by this fact, is exceedingly unsatisfactory. Though the heads of comets contained a small opaque nucleus, there is an obvious reason why it could never obscure the visibility of stars even of the smallest magnitude. The vaporous matter which surrounds such a nucleus, from the increasing density which it exhibits towards its centre, where the nucleus, if any, ought to be, is probably calculated, like atmospheric materials, to refract the rays of light in such a manner, that the small nucleus of a comet could never conceal from view an object so distant as a fixed star.

The other fact that appears to militate against the rotatory motion of comets, is, that the larger comets which present the appearance of a minute stellar nucleus, never exhibit phases, though there can be no doubt that they shine by the reflection of solar light. The evidence for the non-rotation of comets afforded by this fact, is also unsatisfactory. The hazy vaporous matter which to a great distance surrounds the point where the nucleus of a comet ought to be, seems both to be somewhat pervious to light, and to have the power of partially reflecting it. But as this hazy vaporous matter, judging from the increase of light which it reflects, increases in density towards the point where the nucleus ought to be; it is by no means improbable, that the amount of light reflected by the nucleus of a comet, is either no greater at all, or so very little greater, than that which is reflected by the denser portions of the vaporous matter by which it is immediately surrounded, as to render it impossible to distinguish the light reflected by the one, from that which is reflected by the other. If this be the case, it is obvious, that the nucleus of a comet might revolve round an axis, and yet no phases be visible. The rotation of distant celestial orbs on their axes, is always a matter of very difficult determination. And in respect to comets, owing to the vaporous matter by which their nucleus to a great distance is always surrounded, the determination of the point under consideration is attended with peculiar difficulties. All other planetary bodies revolving round the sun, appear to have a rotatory motion round their axes, besides their progressive motion in their orbits; and it would be a departure from the analogies of nature, if comets should have merely a progressive motion, without also being subject to rotation round their axes. Upon the whole it seems probable, that comets have a rotatory motion upon their axes, as well as a progressive one in their orbits, though the former of these has never yet been satisfactorily determined by observation.

Supposing that comets do revolve on their axes, it may be inferred, that their rotation is produced, and maintained, by the same means as those we assigned for the rotatory motion of the planets.

The orbitual movements of comets we would ascribe to the conjoint influence of the centripetal force, and the cause which we assigned for the centrifugal velocity of planets in their orbits. From the extreme elongation of the elliptical orbits in which comets revolve round the sun, and the great mean distances of their orbits from that luminary, it may be inferred, that the sun's rotation has little influence in assisting the orbitual centrifugal velocity of comets, even in those cases when the direction of their orbitual revolution coincides with that of the sun's rotation; and equally little influence in retarding it, when it happens to be in the opposite direction. When the comet's orbitual revolution coincides less or more with the direction in which the sun revolves on its axis, the sun's rotation, agreeably to our theory, should have the effect of causing it to revolve in a more extended orbit than it would otherwise do. And, on the contrary, when the direction of the comet's orbitual revolution is more or less opposed to that of the rotation of the sun, the influence of the sun's rotation should cause it to revolve in a less extended orbit.

While comets are approaching the sun, the velocity of their motion increases, and their tail enlarges; and, on the contrary, while receding from the sun, the velocity of their motion diminishes, and the tail becomes less, and dies away, in consequence of being apparently absorbed into the head, the light of which growing continually feebler, till it at length altogether vanishes from our sight. The dimensions of the tails of comets are by no means proportional to their brilliancy otherwise; nor is the tail even one of their invariable characteristics. Some of the brightest comets have been observed to have had short and feeble tails; and many of them, particularly of the smaller class, have been entirely destitute of such an accompaniment. On the other hand, the tails of comets are sometimes of immense magnitude. Sir John Herschel says, *"The tail of the great comet of 1680, immediately after its perihelion passage, was found by Newton, to have been no less than 20,000,000 of leagues in length, and to have occupied only two days in its emission from the comet's body! a decisive proof this of its being darted forth by some active force, the origin of which, to judge from the direction of the tail, must be sought in the sun itself. Its greatest length amounted to 41,000,000 leagues, a length much exceeding the whole interval betwixt the sun and the earth. The tail of the comet of 1769 extended 16,000,000 leagues, and that of the great comet of 1811, 36,000,000. The portion of the head of this last comprised within the transparent atmospheric envelope which separated it from the tail, was 180,000 leagues in diameter. It is hardly conceivable that matter once projected to such enormous distances, should ever be collected again by the feeble attraction of such a body as a comet—a consideration which accounts for the rapid progressive diminution of the tails of such as have been frequently observed."

Regarding the supposed origin of comets, we

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* Lardner's Cabinet Cyclopedia, article 'Astronomy,' paragraph 487.

will here insert an extract from an able paper on Comets in the CIX No. of the Quarterly Review, page 229. "La Place and Herschel both ascribe the origin of comets to the vast quantity of nebulous matter that is scattered throughout space—sometimes like extensive clouds, sometimes in small patches, and not unfrequently so like comets, that they are only distinguished from these bodies by remaining motionless. Sir William discovered 2000 nebulæ in the northern hemisphere alone; these his son has already increased to 2500, and in all probability, he will double the number before he finishes his interesting observations in the southern half of the heavens. The nebulæ seem to be in various states of condensation—some just beginning to form, and appearing like a flimsy veil of gauze, scarcely visible even in the darkest night with the best telescopes—while others are so far advanced towards the solid state, that they resemble bright stars seen through a haze. Comets are supposed to have been minute nebulæ within the sphere of the sun's action, which, by the mutual attraction of their particles, have become sufficiently dense to be attracted by the sun, and compelled to move in orbits round him. Sir William has observed, that, on their approach to the sun, the subtile fluids are driven off into the envelopes and tail, while the denser parts are consolidated; that, in retreating from the sun, a great portion of the envelopes and tail is dissipated, and lost in space; and he concludes, that, by a repetition of this process, a solid is at length formed, or perhaps the whole dissipated, according to the nature and circumstances of the primitive nebulous mass. The consolidation will be soonest effected in the comets that come nearest to the sun, and return most frequently towards him; and the rotation of a comet will hasten the process, by diminishing the gravitation of the particles, and facilitating evaporation. The hypothesis of the nebulous origin of comets accounts for the length of their orbits; for as they begin their motions at a prodigious distance from the sun, they consequently must return to the same point at each revolution, provided they move in oval paths. It likewise explains the cause of the great obliquity of their orbits to the plane of the ecliptic, and why their motions are sometimes direct and sometimes retrograde."

What comes of the repelled materials which comets are supposed to lose at each perihelion passage, has never, so far as I know, been conjectured. But if comets come nearer the sun at each succeeding revolution till they are entirely dissipated, as has been conceived; it is possible, that the vast quantity of nebulous matter scattered throughout space, which, in the preceding extract, is referred to as the source from whence comets originate, may be accumulations, in distant quarters of the heavens, of the dispersed materials of which comets have been previously composed. These materials, after gradually concentrating for ages by the force of attraction, may re-assume the appearance of comets, and may perform a series of revolutions round the nearest sun by which they are attracted, till they be again entirely dissipated by his influence. This addition to the preceding hypothesis completes the circle, by making the materials of which comets are composed, return to the source from whence they came. The hypothesis, however, is entirely conjectural, and therefore entitled to no attention. Nevertheless, it is much more likely to be true, than that the gradual concentration of those diffused nebulous masses, should ultimately give birth to planetary systems, with all their revolutionary movements.

A variety of opinions have been entertained by astronomers, regarding the nature of the tails of comets. Appian, Cardan, and Tycho Brahe, supposed them to be the light of the sun transmitted through the nucleus of the comet, which they believed to be transparent like a lens. Descartes ascribed the tail to the refraction of light by the nucleus. Kepler and Euler conceived that the tail is occasioned by the impulsion of the solar rays driving off the atmosphere of the comet; and Euler farther imagined, that the curvature observed in the tail is the joint effect of this impulsive force, and the gravitation of the atmospherical particles to the solid nucleus. Newton maintained, that the tail consisted of a thin vapour, raised by the heat of the sun from the comet. And Biot supposed with Newton, that the tails are vapours produced by the excessive heat of the sun; and also that comets are solid bodies before they reach their perihelion, but that they are afterwards converted either partly, or wholly, into vapour by the intensity of the solar heat.

When it is considered that light is only reflected by material particles which have the power of arresting, and possibly, by means of attraction, of concentrating it; and that without the aid of such material particles, light, so far as we know, never becomes visible; it may be inferred, that the tails of comets consist of material particles which have the power of reflecting light. The opinion, therefore, entertained by Newton and Biot, that they consist of substances vaporized in the same manner as water around us is vaporized by the heat of the sun, seems to be a plausible hypothesis. And when it is farther considered that the tails enlarge while comets are approaching the sun; and diminish while they are receding from it, until they apparently become absorbed into their heads; we are led to extend the supposition of Biot, and to believe, that comets are solid bodies throughout the greater part of their orbitual revolution, (a supposition favourable to that of their rotation;) and that it is merely when near their perihelion passage, which is the only time they are visible to us, that they assume the vaporous appearance that distinguishes them from other planetary bodies.

Our principal object, however, for introducing these details regarding comets, is to support our theory, by the evidence thereby afforded of the existence of a repellent force exerted by the sun towards distant celestial bodies, as well as an attractive force. The fact of the tails of comets being always turned away from the sun, both in their approach, and in their retreat from that luminary, indicates not merely the existence of a repellent force in the sun, but likewise that the united ponderable and imponderable materials of which the tails of comets may be conceived to consist, are more strongly repelled by the sun, than the materials of which their nuclei are composed. And this greater liability to be repelled by the sun, probably results from the tails of comets consisting of a larger proportion of caloric or other imponderable repelled substances, relative to the amount of ponderable attracted materials, than their nuclei.

Upon this point we will only farther remark, that if it be admitted that a portion of the materials contained in comets is repelled by the sun, it may be inferred, that a portion of the materials contained in all other planetary bodies is also repelled by the sun. And judging from the fact of the particles of caloric being mutually repellent; and also from the phenomena of solar radiation, particularly the absorption of caloric by the land and water composing the surface of the earth during day, and its retrocession therefrom during night; it may be likewise inferred, that caloric, and probably the other imponderable bodies, held in attraction by the ponderable materials of which the earth consists, are the substances which are repelled by corresponding materials contained in the sun. And hence, in accordance with our theory, we are led to the ultimate conclusion, that the inequality in the distribution of these imponderable substances around the surface of the earth, and that of other celestial orbs; and which unequal distribution is produced, and perpetuated, in the manner we have described, is the cause to which the rotation, and all other centrifugal movements of planetary bodies, should be directly or indirectly attributed.

SECTION XVI.

HYPOTHETICAL EXPLANATION OF THE DIFFERENCE IN THE DENSITIES OF PLANETARY BODIES.

The densities of the different planets, with the exception of the Georgium Sidus, seem to diminish somewhat in proportion as their mean distances from the sun increase. This will appear from an inspection of the following Table:

Names of the Planets.	Mean Distances from the Sun in round numbers of Miles.	Densities, that of Water being 1.
The Sun, .		$1\frac{2}{15}$
Mercury, . .	37,000,000	$9\frac{1}{6}$
Venus, . .	68,000,000	$5\frac{11}{15}$
The Earth, .	95,000,000	$4\frac{1}{2}$
The Moon, .	95,000,000	$5\frac{1}{2}$
Mars, . . .	144,000,000	$3\frac{2}{7}$
Ceres, . .	263,000,000	2
Pallas, . .	265,000,000	2
Jupiter, . .	490,000,000	$1\frac{1}{24}$
Saturn, . .	900,000,000	$0\frac{11}{32}$
Georgium Sidus,	1,800,000,000	$0\frac{22}{100}$

The exception in the case of the Georgium Sidus, is generally supposed to arise from some inaccuracy in the observations made on so distant a planet; or from some undiscovered error in the mode of estimating. Judging, however, from the fact of the increase in the mean distances of the other planets from the sun, not bearing a strict proportion to their estimated decrease in density, I consider it more probable, that the exception in the case of the Georgium Sidus, is merely a farther departure from that relation. At the same time, the circumstance of there being a tolerable approximation towards a strict relation between the density of planets, and the mean distances of their orbits from the sun, leads me to think, that their mean distances from the sun, is not an arbitrary arrangement dependent on no material or physical cause, but is the result of some circumstance that affects, and is intimately connected with, though not entirely dependent upon, the density of ponderable materials. Our distance from all other planetary bodies, precludes the possibility of ascertaining from actual observation, what is the cause of the difference in the mean density of the materials of which they severally consist. And the only knowledge we can ever obtain on this point, is limited to conjectural inferences, deduced from an inquiry into the cause of the different densities of the various substances composing the crust of the earth.

On examining the various substances composing the crust of the earth, we find there is a general, though not a strict relation, between their density, and their capacity for caloric, or as it is more frequently called, their specific heat. With regard to gaseous substances, the relation is strictly proportional. Thus, the same volumes of all gases, under an equal pressure, are found to have the same specific heat. Consequently, the specific heats of all gases, reckoned by weight, are inversely as their specific gravities or densities. With regard to liquids and solids, it appears that their density is in general less, according as their specific heat is greater. But the relation subsisting between these two characteristics, deviates considerably from any strict proportion in different simple substances; and still more in compounds. Thus bismuth, lead, and gold, are specifically lighter, and accordingly not so dense as platinum; and yet their specific heat is less. Alcohol is considerably less dense than water; yet, instead of having a greater specific heat, it has a less one, in the proportion of 602 to 1000. And the specific heat of water compared to that of mercury, is as 20¼ to 1; while the difference in their density, is only as 1 to 13½.

The fact of the specific heat of different gases, estimated by weight, being always inversely proportional to their densities, leads us to the conclusion, that, but for modifying circumstances, the capacities of all bodies for caloric, result from, and would be strictly proportional to their attraction for it. And when it is considered that all bodies upon being condensed, whether by chemical combination or compression, evolve caloric, and have their specific heat thereby reduced; it may be inferred, that the deviations in the specific heats of different ponderable substances, whether simple or compound, from being inversely proportional to their densities, result from different degrees of attraction which they exert for caloric, modified by variations in the extent of condensation, produced by mechanical pressure, or by different degrees of affinity mutually subsisting between different ponderable particles.

By way of explaining analogically, the probable reason why the Georgium Sidus deviates from the general law of planets being less dense, as their orbits are more distant from the sun, we shall endeavour to point out the cause, why the specific heat of water, deviates so much from being inversely proportional to its density. Water is a compound of hydrogen and oxygen, the specific heats of which, relative to those of water and air, are as under:

	Specific heat, same weight.
Water,	1·0000
Air,	0·2669
Hydrogen,	3·2936
Oxygen,	0·2361

From the above Table it appears, that the capacity of hydrogen for caloric, is 16 times as great as that of oxygen, the other element of water. And agreeably to the principle previously laid down, that the capacity of all bodies for caloric, except for modifying circumstances, is proportional to their attraction for it, hydrogen exerts 16 times the attraction for caloric that oxygen does. Now, as the attractive, as well as the repulsive forces, which bodies exert towards each other, are constant quantities, whether the body be considered separate from others, or be chemically combined with them; it is obvious, that the great specific heat of water relative to its density, is owing to its hydrogen, which has a much greater capacity for caloric than any other substance known. And hence, particles of hydrogen, in consequence of their strong attraction for caloric, are enabled to concentrate a much larger amount of it than other substances, even when counteracted by the modifying circumstance of being chemically combined with oxygen, and condensed into the state of water, by the attraction of the opposite electric fluids held in affinity by the separate elements of water.

Now, supposing the Georgium Sidus to consist of substances whose mean capacity for caloric is greater than those of Saturn, but which, like the elements of water, are condensed by a strong affinity for each other; it is obvious, that it may contain a greater amount of caloric, or other imponderable materials, relative to the amount of ponderable matter, and yet be more dense than Saturn. A similar explanation may be given, of the decrease in the densities of the planets deviating somewhat from a strict relation to their mean distances from the sun. Judging from analogy, therefore, we infer, that the difference in the mean distances of all planetary bodies from the sun, is proportional, not to their difference in density, but to a circumstance that affects, and is intimately connected therewith, viz. a difference in the mean capacity of their ponderable materials for caloric. And in accordance therewith, we farther infer, that planetary bodies, including comets, are severally composed of a larger proportion of caloric, (and possibly other imponderable materials,) relative to the amount of ponderable matter, according as the mean distance of their orbits from the sun is greater.

SECTION XVII.

ON THE CAUSE OF THE DIFFERENCE IN THE MEAN DISTANCES OF PLANETS FROM THE SUN.

We now come to inquire whether the difference in the mean distances of planets from the sun is an arbitrary arrangement, dependent on no material or physical cause; or whether it is the necessary result of a difference in the relative proportion of attractive and repulsive forces, mutually subsisting between, and inherent in the ponderable and imponderable materials, of which the sun and different planetary bodies are respectively composed. From the expansion which all ponderable substances around us undergo with increase of temperature, we are led to think, that the atoms or particles of which they are composed, upon acquiring an additional amount of caloric, have a tendency to separate farther from each other. From analogy may we not infer, that the mean distances of the orbits of all planetary bodies, including comets, from the sun, necessarily becomes greater, according as they are composed of a larger proportion of caloric and other imponderable mutually repellent materials, relative to the amount of ponderable matter, which exerts no force but attraction?

The notion that planets differ in density, is merely an inference, deduced from the fact of their mutually exerting different degrees of attractive force, relative to their bulk, upon satellites and other planetary bodies. And it has been found, that the attractive force relative to the bulk, which they severally exert upon other planetary bodies, diminishes nearly in proportion as the mean distance of their orbits from the sun increases. Now, if the different planetary bodies be viewed as aggregations of ponderable and imponderable materials, mutually actuated by their respective attractive and repulsive relations; it is obvious, that if the quantity of caloric, or other mutually repellent materials in any planetary body be increased, while the amount of mutually attractive ponderable substances remains unaltered, the preponderance of the attractive over the repulsive forces will be thereby diminished. Consequently, such planetary body viewed as an aggregate of materials in part mutually attractive, and in part mutually repellent, the former preponderating, should exert a less degree of attraction upon other planetary bodies, even though its density were to remain unaltered. Agreeably, therefore, to the explanation now given of the diminution in the attractive force exerted by planetary bodies relative to their bulk, according as the mean distance of their orbits from the sun increases, we infer, that the mean distance of the orbits of planets from the sun, is not an arbitrary arrangement dependent on no material or physical cause; but is determined by the relative proportions of the ponderable and imponderable materials of which they severally consist; and that an increase of distance from the sun, is the necessary result of their being composed of a larger proportion of caloric, or other imponderable materials, relative to the amount of ponderable matter. We are likewise led to the same conclusion, by the fact, to which we had occasion to advert when commencing our observations "On the Cause of the Centrifugal Velocity of Planets in their Orbits," viz. that the preponderance of the attractive over the repulsive forces exerted by the sun towards any planet, requires to be greater, according as the planet revolves in a smaller orbit. Now, every diminution in the amount of caloric or other repelled materials in any planet, without a corresponding diminution of the attracted substances, must increase the preponderance of the attractive over the repulsive forces, which the sun exerts towards it; and consequently must cause it to revolve in a smaller orbit.

Agreeably to the preceding hypothesis, that the mean distances of planets from the sun is determined by the relative proportions of the ponderable and imponderable materials of which they severally consist; it follows, that if the orbits, and the rotatory velocities of two planets could be exchanged, they would gradually regain either their former orbits, or others, whose mean distance from the sun was the same as that of their former orbits. For instance, let us suppose that Jupiter was transferred to the orbit of the earth, and the earth to that of Jupiter; and that the rotatory and orbitual velocity which the earth at present has, was communicated to Jupiter; and the rotatory and orbitual velocity which Jupiter at present has, was communicated to the earth. In such circumstances, agreeably to our hypothesis, they would gradually regain either their former orbits, or others, (probably more eccentric ones,) whose mean distance from the sun was equal to that of their former orbits.

Supposing Jupiter in the earth's orbit, I conceive that the great accumulation of caloric around its surface compared to that by which the earth is encompassed, would, during its rotation, cause the amounts of caloric contained in, and concentrated around its hemispheres to the east and west of the meridian where the sun was vertical, to be much more unequal, (and which would cause the repellent force exerted towards them by the sun to be proportionally more unequal,) than the amounts of caloric contained in the corresponding terrestrial hemispheres are at present. The consequence of this would be, that its rotatory velocity would be increased beyond what the earth's is at present; and the orbitual centrifugal velocity, being also thereby rendered too strong for the centripetal force, would cause its orbit to extend in every revolution, till it attained the dimensions of that in which it at present revolves. On the contrary, supposing the earth transferred to Jupiter's orbit, I conceive that the reason above assigned for an increase in the rotatory and orbitual centrifugal velocities of Jupiter in the earth's orbit, would be reversed. The repellent influence of the sun, weakened by increased distance, would be inadequate to produce such an inequality in the amount of caloric in the hemispheres to the east and west of the meridian where the sun was vertical, as would enable it to support either the rotatory, or the orbitual centrifugal velocity of Jupiter. Consequently, its rotatory velocity would gradually diminish; and the centripetal force being too strong for its orbitual centrifugal velocity, would cause the diameter of its orbit to diminish gradually in each revolution round the sun, till it again moved in one whose mean distance from the sun was no greater than that in which it at present revolves.

Though the mean distance of planets from the sun be principally determined by the influence of that luminary in the manner now described, it is also appreciably modified by the mutual preponderance of attractive over repulsive forces, exerted by the planets towards each other. Thus the orbits of Mercury and Venus are appreciably extended beyond what they would otherwise be, by the attractive influence of the planets which revolve in more distant orbits. And, on the other hand, the orbits of Saturn and the Georgium Sidus are diminished in extent, and their periodic times are shortened, by the attraction of those planets that revolve in smaller orbits. The orbits of all the planets must also be extended, (and those nearest the sun must be most so,) by the rotation of the sun being performed in the same direction as the planets revolve round him. And had they revolved in an opposite direction, the extent of their orbits would have been thereby proportionally reduced. In short, the mean distance of the orbits of the several planets from the sun, and their mean revolving velocities, are determined by a combination of permanent causes, which confer on the solar system the attribute of everlasting stability. And were any accidental influence, such as the near approach of a comet, to extend, or diminish, the dimensions of any planet's orbit; the self-rectifying and compensating principles which we have pointed out, would soon cause it to return to an orbit, whose mean distance from the sun was similar to that in which it now revolves.

SECTION XVIII.

ON THE CAUSES WHICH DETERMINE THE MEAN DISTANCES OF SATELLITES FROM THEIR PRIMARY PLANETS.

The mean distance at which the orbitual revolution of the moon round the earth is performed, instead of being an arbitrary arrangement, is also determined by physical causes. But as the orbitual revolution of the moon round the earth, is produced in a different manner from that of the earth and moon round the sun; so the mean distance of the moon's orbit from the earth, is likewise determined by causes partly different from those which regulate the mean distance of the orbits of planets from the sun.

In Section X. we endeavoured to show that the centrifugal velocity exhibited by the moon's orbitual revolution round the earth, was occasioned by a portion of the earth's rotatory velocity being communicated to the moon. The attractive influence exerted by the earth upon the side of the moon which is nearest, being stronger than what is exerted upon that which is most distant, the moon's rotation is thereby counteracted. But the same force that counteracts the moon's rotation, by exerting an influence which we compared to a slight degree of adhesion subsisting between the sides of the earth and moon that are nearest each other, has the effect of imparting an orbitual movement to the moon round the earth, in the direction that the earth turns on its axis.

Now, this attractive force, which, by acting in conjunction with the earth's rotation, causes the orbitual revolution of the moon, increases inversely as the square of the distance. Accordingly, if the distance of the moon's orbit from the earth were diminished one-half, both the centripetal tendency, and the centrifugal force caused by the communication of the earth's rotation to the moon, would be increased fourfold. But a double increase of centrifugal force acting at right angles to the centripetal, balances a quadruple increase in the power of gravity. Hence it is evident, that the centrifugal velocity of the moon at half its present distance from the earth, would be double what was requisite to balance the centripetal force, and this consequently would extend the moon's orbit.

On the other hand, if the distance of the moon's orbit from the earth were double what it now is, both the centrifugal force caused by the communication of the earth's rotation to the moon, and the centripetal tendency, would be diminished to one-fourth of what they are at the moon's present distance from the earth. But a twofold diminution of centrifugal force, balances a fourfold diminution in the power of gravity, Hence it is evident, that such a decrease of centrifugal force as would result from doubling the distance of the moon's orbit from the earth, would render the moon's centrifugal velocity one-half too weak, to counterpoise the centripetal tendency; and consequently the moon's orbit would diminish. Such is the manner in which every deviation of the moon from its present orbit is prevented. Every increase in the size of its orbit, would cause the centripetal force to be too strong for the centrifugal; and every diminution of its orbit, would cause the centripetal force to be too weak to balance the centrifugal.

The preceding explanation of the cause which prevents any deviation of the moon from its present orbit, affords a solution of another difficulty. As the earth's rotation only communicates centrifugal velocity to the moon either at a right angle, or on an average at a right angle to the centripetal force, it might be supposed, that the centripetal tendency of the moon towards the earth could have no influence, except what was temporary and periodic, in either accelerating or retarding the moon's orbitual velocity. From the earth's turning on its axis in shorter time than the moon performs her orbitual revolution round it, it might be imagined, that the rotation of the earth should constantly accelerate the moon's orbitual velocity, till its revolution round the earth, was performed in as short time as the earth turns on its axis. The reason why this is not the case, is to be ascribed to the counteraction presented to the enlargement of the moon's orbit, by the increasing preponderance of the centripetal force over the centrifugal, as the orbit extends. In short, the moon's present orbit may be considered so far extended by the circumstance under consideration, that the preponderance of the centripetal over the centrifugal force, acts as a counterpoise to the constant accession of centrifugal impulse, which the rotation of the earth is perpetually communicating to the moon.

Again, as the moon's orbitual revolution is caused by the earth's rotation, it is evident that the mean distance of the moon's orbit from the earth, is regulated by the earth's rotatory velocity. If the earth's rotatory velocity were less than it is, the centrifugal velocity communicated thereby to the moon, at its present distance, would also be less. In that case, the centripetal tendency would be too strong for the centrifugal; and consequently, would cause the moon to revolve in a smaller orbit than it now does. On the contrary, if the earth's rotatory velocity were greater than it is, the centrifugal velocity thereby communicated to the moon would likewise be greater. In that case, the centripetal tendency would be too weak to balance the centrifugal; and the moon's orbit would consequently extend, till the equilibrium between these two forces was restored. As the rotatory velocity of the earth, however, undergoes no change, it may be concluded, that the mean distance of the moon's orbit from the earth, must likewise continue without variation.

The reason we would assign for the four satellites of Jupiter, and the seven of Saturn, revolving at different distances from their primary planets, is the same as that which we advanced, as the chief cause of the difference in the mean distances of the planets from the sun. If satellites be unequally attracted by their primary planet, while they are subjected to the same centrifugal influence, it necessarily follows, that those with the least centripetal tendency, will revolve in the largest orbits, and with the least rapidity. Hence we infer, that the satellites of Jupiter and of Saturn revolve in orbits of unequal dimensions, in consequence of being composed of unequal relative proportions of ponderable and imponderable materials. Those which consist of the largest proportion of ponderable attracted matter, relative to the amount of imponderable or repelled materials, should be most strongly attracted by their primary planet; and accordingly should revolve with greatest velocity, and in the smallest orbits.

Upon contemplating the planetary arrangement of the solar system, we are struck with the simplicity of its design, and with the fitness in the means adopted to secure and maintain its stability. If planets or satellites accelerate or retard the velocities of each other at one part of their orbits, they produce, in an equal degree, the opposite effect at another. Were another satellite added to those of Jupiter, and so constituted as to revolve in a smaller orbit than any of his present attendants; the only influence it could have, would be slightly to diminish the size of the orbits of his present satellites, and shorten their periodic times. If, on the other hand, this additional satellite were so constituted as to revolve exteriorly to all his present satellites; it would slightly extend their orbits, and lengthen their periodic times, but could not otherwise disturb their movements. An extended survey of the solar system, thus shows that it is governed by self-adjusting and compensating principles, which preclude the possibility of its structure being injured, or its movements suspended. And though additional planets were created, or existing ones annihilated, the same self-adjusting principles which at present regulate the movements of all celestial orbs, and determine the distances between them, would instantly re-organize a new planetary arrangement, equally simple and harmonious, and equally permanent and indestructible, as that which we now contemplate.

SECTION XIX.

ON THE RETROGRADE MOVEMENT OF THE SATELLITES OF THE GEORGIUM SIDUS IN THEIR ORBITS.

Besides the deviation from the law of planets being less dense according as their mean distance from the sun is greater, the Georgium Sidus presents another anomaly, which we previously noticed, viz. that of its satellites revolving in their orbits, in a retrograde direction to that in which all other satellites in the solar system revolve round their primary planets. Though the extreme distance of the Georgium Sidus from the earth, has rendered it impossible to ascertain by accurate observation in which direction it revolves on its axis, it has been inferred from analogy, that its rotation is performed in the same direction as that of the other planets, viz. from west to east. Admitting this inference to be correct, it is obvious, that the orbitual movements of its satellites in a retrograde direction to that in which it revolves itself on its axis, cannot be explained upon the same principle, as the orbitual movement of the moon, and other satellites, round their primary planets, was accounted for.

The most obvious principle according to which the orbitual movements of the satellites of the Georgium Sidus can be explained, agreeably to our theory, requires us to suppose that their rotation on their axes is performed in shorter time, than their orbitual revolution round their primary planet. In consequence of the immense distance of the orbit of the Georgium Sidus from the sun, it is evident, that the sun's attractive and repellent forces, can have exceedingly little influence in communicating either a centripetal, or a centrifugal tendency to the satellites of that planet, in comparison with the influence of the planet itself. To obviate the objection to our theory presented by the retrograde movement of the satellites of the Georgium Sidus, it is only necessary therefore to suppose, that rotation and orbitual movement, are communicated by the Georgium Sidus to its satellites, upon the same principle as the sun communicates rotation and orbitual movement to the earth; and that the revolution of the satellites of the Georgium Sidus round him, is performed independently of the influence of the sun, in causing the Georgium Sidus, and his satellites, to revolve slowly round him, in the lengthened period of about 83½ years.

If the hypothesis advanced in Section XVII. be correct, viz. that the mean distances of planets from the sun becomes greater, according as they are composed of a larger proportion of caloric, relative to that of ponderable matter, the deviation, in the case of the satellites of the Georgium Sidus, from the law of the rotation and orbitual revolution of satellites, being performed in equal times, appears more probable, when it is considered, that their primary planet, though double the distance from the sun, is nearly three times as dense as Saturn. This circumstance leads us to think, that the proportion of caloric concentrated around its surface, relative to that which is intermixed internally with its ponderable materials, must be unusually large. And if its satellites be similarly constituted, it is probable that the inequality in the distribution of caloric over the surface of their different hemispheres, and the consequent inequality in the calorific repulsion exerted towards them by their primary planet, may be so strong, as to produce and maintain a rapid rotatory movement, in opposition to that attractive influence, which, in other similar cases, prevents the rotation of the satellites being performed in shorter time, than their orbitual revolution. If this supposition be well founded, the rotation of the satellites of the Georgium Sidus, and their orbitual centrifugal velocity, should result from the hemisphere of the satellites, that during rotation has passed the meridian over which the planet is vertical, being more heated, and consequently more repelled by the caloric contained in and concentrated around their primary planet, than the hemisphere whose foremost boundary line has just reached that meridian. In short, the explanation of the retrograde direction in which the satellites of the Georgium Sidus revolve in their orbits round their primary planet, is perfectly analogous to that previously given of comets that revolve round the sun in a retrograde direction.

It is by no means improbable, that if the inclination of the axis of this distant planet to the ecliptic were ascertained, it might tend to throw light on the anomaly we have been considering. On this point we will only farther remark, that the retrograde movement of the satellites of the Georgium Sidus, is utterly subversive of the projectile theory, which supposes that planets acquired their centrifugal velocity, in consequence of being thrown off from the sun by its too rapid rotation on its axis; and that satellites, in like manner, acquired their centrifugal velocity, in consequence of being thrown off by the too rapid rotation of their primary planets.

SECTION XX.

OBSERVATIONS ON A SUPPOSED RESISTING MEDIUM.

It has long been, and still continues to be, a matter of uncertainty, whether the celestial spaces through which planetary bodies revolve in their orbits, be entirely void of matter, or be filled with some etherial fluid of extreme tenuity. The latter of these opinions has recently been most generally received; and is even considered by many to be completely established. The only evidence of the existence of an etherial fluid that I can find, are inferences deduced, first, from the gradual acceleration in the periodic returns of two comets; and, second, from the tails of comets before reaching their shortest distance from the sun, being gradually bent more or less towards the region the comet has left; the bending being greater as the distance from the head increases, exactly as if it met with resistance in passing through some fluid. And this inference is considered more probable, by the tail being better defined, and more luminous, on the side towards which the comet is moving, than on the other. We will examine these two points in their order.

Encke's comet, which revolves between the orbits of Mercury and Pallas in about 1208 days, retreating from the sun, at one time, as far as 443 millions of miles, and coming as near him at another, as 34 millions of miles, is said to complete each successive revolution round the sun, in about two days' shorter time than it did the preceding. And Biela's comet, revolving between the orbits of the Earth and Jupiter, is accelerated something less than one day at each revolution. From the circumstance of Encke's comet coming nearer the sun, and its periodic time being more accelerated at each revolution than Biela's, it has been also supposed, that the ethereal fluid increases in density towards the sun. And from the gradual retardation of the centrifugal velocity of these comets conceived to be produced by the ethereal fluid, and the consequent diminution in the size of their orbits, it has been farther supposed, that they must ultimately fall into the sun, if they are not previously entirely vaporized, and dissipated by his heat.

The evidence of the existence of a resisting ethereal medium, afforded by the gradual diminution in the periodic times of these comets, becomes much less conclusive, in consequence of the phenomena admitting of being otherwise accounted for. If the cause be correct which Sir John Herschel has assigned for the rapid progressive diminution of the tails of such comets, as have been frequently observed, during their successive periodic returns, viz. that matter once projected to such enormous distances as the tails are, could hardly be conceived to be again collected by the feeble attraction of such a body as a comet. And if the matter of which the tail is composed be driven away from the sun, in consequence of containing a larger proportion of caloric relative to the amount of ponderable matter, than that which constitutes the nucleus of the comet, as we have supposed; there is an obvious reason for the diminution in the orbits of such comets, without any assistance from a resisting medium. Provided a portion of the most strongly repelled materials composing its tail, or in the case of a comet having no visible tail, provided a portion of its most highly repelled elastic vapour be driven off altogether from the comet, by the sun's repellent materials, each time it comes to its perihelion distance; it follows, that the comet, after each perihelion passage, will consist of a smaller proportion of repelled materials relative to the amount of attracted matter, than it did before. And considered as an aggregate body, consisting of materials partly attracted, and partly repelled by the sun, it is obvious, that the preponderance of the attractive over the repulsive forces exerted towards it by the sun, will be thereby increased. Hence we conclude, that so long as a comet continues to lose, during each perihelion passage, a larger proportion of its repelled than of its attracted materials, the extent of its orbit, and its periodic time, may be expected to undergo a proportional diminution.

Though Encke's comet has no visible tail, yet the fact of its becoming less and less conspicuous at each re-appearance, favours the preceding hypothesis, in so far as it indicates, that a portion of its substance is dissipated, and driven away, each time it approaches the sun. And when it is considered, that Encke's comet, at its perihelion, comes nearer the sun than the orbit of Mercury; whereas Biela's comet never comes nearer the sun than the orbit of the earth; it is probable that the greater acceleration in the periodic time of the former, at each successive revolution, may be owing to a greater loss of highly vaporized fluid, caused by the repulsion of the repellent materials contained in the sun, in consequence of its nearer approach to that luminary.

The other fact adduced in support of the hypothesis, that the spaces through which the planetary bodies revolve in their orbits round the sun, is occupied by an ethereal fluid, or resisting medium, viz. that a little before a comet reaches its shortest distance from the sun, its tail is gradually bent more or less towards the region the comet has left; the bending being greater as the distance from the head increases, exactly as if it met with resistance in passing through some fluid. And this supposition is considered more probable, by the tail being better defined, and more luminous, on the side towards which the comet is moving, than on the other. The evidence afforded by the above stated phenomena of the existence of an ether filling space, is also inconclusive, in consequence of the phenomena admitting of being otherwise explained in an equally satisfactory manner. The tails of comets being always turned away from the sun, it is evident, that while a comet is rapidly turning round the sun as it approaches its perihelion, the particles composing its tail, according as they are more distant from the nucleus, will have to perform a longer circuit; and of course will have to move with proportionally greater speed, in order that the tail may retain its usual position, in reference to that of the nucleus of the comet, and the sun. As the matter composing the tail of the comet seems to be more strongly repelled by the repellent materials contained in the sun, than the matter composing its nucleus; and as the particles of the comet's tail will be less attracted by the head of the comet, according as they are more distant from it; it is evident, that the curvature of the extremity of the tail during the comet's perihelion passage round the sun, and the better defined, and the more luminous appearance presented by the side of the tail towards which the comet is moving, than by the other, might with equal plausibility be attributed, to the resistance offered by the repulsion of the repellent materials contained in the sun, to the increasing speed, which the particles of matter composing the tail require, according to their greater distance from the comet's nucleus.

Having thus shown that all the phenomena upon which the hypothesis of a resisting medium rested, can be otherwise accounted for; we will now proceed to assign reasons for believing that nothing of the kind exists.

Upon surveying the various arrangements of nature, we are every where so struck with the wonderful adaptation of means to accomplish useful ends, as to be impressed with the belief, that nothing has been created in vain. But no useful purpose can be pointed out, which an ethereal fluid occupying space could serve. According to the commonly received notions of planetary motion, the existence of a resisting medium would gradually tend to diminish the orbits, not only of comets, but of all other planetary bodies, till they at length fell into the sun. Now, with the exception of the two comets, the retardations in the periodic times of which we have shown might be otherwise accounted for, all the evidence we have, tends to prove, that the periodic times of the different planets of the solar system, are neither undergoing, nor have undergone, the slightest perceptible diminution, or alteration.

Again, a hypothesis which implies a belief in a tendency of the mechanism of the universe towards self-destruction, is refuted by all the analogies of nature. The principles of reproduction in the animal and vegetable kingdoms, as well as all other physical arrangements, indicate a self-perpetuating, and never-ending character. All human experience, and the progressive advancement in scientific investigation, by obviating the various objections that have been successively urged in order to overthrow the doctrine of the permanent stability of our system, has but tended to its confirmation. The attribute of highest perfection in mechanical movement and structure, is that of a machine possessing within itself, the properties of perpetual motion, and eternal durability. And when it is considered that the Being who created the universe, had wisdom and power to perfect his works, any hypothesis requiring us to believe, that the celestial mechanism is destitute of this highest attribute of perfection, can hardly be regarded in any other light, than as containing internal evidence of its own fallacy.

Again, if any ethereal fluid be universally diffused throughout unoccupied space, it can only exist in that state, in consequence of its particles being mutually repellent; and the resistance which such a fluid would present to the passage of any planetary body through it, would be proportional to its density, and the degree of repellent force by which its particles were mutually actuated. Now, though the earth moves in its orbit round the sun with the astonishing velocity of 68,080 miles an hour, which is equal to 1134 miles a minute, no evidence is thereby afforded of a resisting medium. If such a thing does exist, it is reasonable to suppose that the weight of the atmosphere, on the side of the earth that is pressing directly against it with such inconceivable force and velocity, should be increased. But no such evidence in support of the hypothesis can be adduced. And the supposition of extreme tenuity seems rather an evasion, than an answer to the testimony, in opposition to the hypothesis, afforded by the want of evidence on this point.

Similar arguments to those immediately preceding may be adduced in opposition to the hypothesis, that the temperature of the celestial spaces through which planetary bodies revolve in their orbits, is 58° below Zero of Fahrenheit, and that caloric, or other imponderable materials, may therefore constitute the resisting medium. That 58° below Zero of Fahrenheit does not constitute the absolute Zero, or absence of all caloric, is evident from the fact of a lower temperature, by at least 30 degrees, having been produced artificially. But in addition to the two preceding arguments, the following reason may be assigned for believing, that neither caloric, nor light, exist distributed throughout the celestial spaces, in any quantity, however small.

Calorific particles, as well as those of light, are mutually repellent. It is evident, therefore, that the particles of caloric, or of light, contained in and concentrated around the atmosphere on the side of the earth which is foremost in the orbit, would repel, and be repelled, by the calorific and luminiferous particles distributed throughout space, with an additional force to that which they are usually subjected to, proportioned to the velocity of the earth in its orbit, viz. 68,080 miles an hour. Now, the fact which proves that neither caloric, nor light, are distributed throughout space in the manner supposed, is, that the greatest diurnal cold, and darkness, are experienced on that side of the earth, which is foremost in the orbit; whereas, the greatest diurnal warmth and light, ought to exist on that side of the earth, if caloric or light had been distributed throughout space, agreeably to the hypothesis under consideration.

Upon the whole, therefore, it must be admitted, that there is some evidence of the existence of a resisting medium. But when it is considered, that an ethereal fluid occupying space could serve no visible useful purpose, save that of ultimately annihilating the solar system, agreeably to the commonly received opinion regarding planetary motion; that its existence is indirectly contradicted by the analogies of nature, as well as by other evidence; and that the phenomena upon which its supposed existence rests, admit of being as satisfactorily, and less objectionably explained otherwise; we are rather inclined to think, that the hypothesis of a resisting medium is erroneous; and accordingly, that it is more probable that planetary bodies with their allotted portions of imponderable materials, revolve in their orbits through space, in which nothing material exists to obstruct their movements. The question, however, is still an open one, and, in the present state of knowledge, must be left to be finally determined by future, and more extended observations.

SECTION XXI.

CONCLUDING REMARKS, WITH OBJECTIONS ANTICIPATED AND ANSWERED.

Having thus endeavoured to explain the cause of centrifugal velocity in planetary motion in all its various details, and extended our subject somewhat beyond what we originally purposed, we must now bring our observations to a close.

The cause we assigned for the rotation of planetary bodies, is the unequal distribution of caloric over the surfaces of their respective hemispheres presented to each other. This, by causing the warmest of the two to be more strongly repelled than the other, by the repellent materials which planetary bodies severally contain, must necessarily produce, and perpetuate their mutual rotation. But this unequal distribution of caloric being calculated merely to produce rotatory motion; and, by means thereof, to perpetuate that inequality in the distribution of caloric, only after rotation has commenced; it may be asked, how did this unequal distribution of caloric originate before rotatory motion existed? To this question we answer, that it is only permitted to man to observe existing phenomena; but not to contemplate either their beginning or their end. From the fitness of the celestial mechanism to perpetuate its movements when once begun, we can form some notion, that such may never have an end. In like manner, from the perception of movements calculated to perpetuate themselves, we can form a notion, though somewhat less distinct, and less suited to our prejudices, and ordinary modes of thinking, than the preceding, that such may never have had a beginning. On the consideration of these points, however, we must decline to enter, not only because the prejudices and preconceived notions of mankind, debar such subjects from being either dispassionately, or philosophically examined; but also because the limited nature of human faculties, precludes us from ever arriving at any certain conclusions regarding them.

But though we cannot show how the unequal distribution of caloric on the surface of the earth, or on that of any other planetary body, originated before rotatory motion existed; we are warranted, nevertheless, to refer to it as the cause of planetary rotation, not only from its fitness to produce the effect, but likewise from the fact, that if it were to cease, planetary motion would soon thereafter terminate. We endeavoured to show how the circumstance of the attractive influence exerted by the earth upon the side of the moon that is nearest us, being stronger, in consequence of greater proximity, than upon that which is turned away from the earth, had the effect of retarding, and so regulating the moon's rotatory velocity, as to produce an equality in the times of her rotation on her axis, and in her orbit round the earth. Now, as a reciprocal, though a less powerful influence, is at all times exerted by the moon in counteracting, and retarding the rotatory velocity of the earth; it is manifest, that if the earth's rotation were not constantly maintained by a stronger repellent force, continually exerted towards the hemisphere immediately past the meridian where the sun is vertical, than what is exerted towards the other, it would gradually diminish in velocity, till it ceased entirely. And if the earth's rotation were to terminate, the orbitual revolution of the moon round it, which we endeavoured to show was thereupon dependent, would, in like manner, gradually come to an end. The same attractive force, the influence of which resembles a slight degree of adhesion subsisting between the sides of the earth and moon that are nearest each other; and which, by communicating a portion of the earth's rotatory velocity to the moon, gives rise to the moon's orbitual revolution round the earth; provided the earth's rotation had ceased, would gradually retard the acquired centrifugal velocity of the moon in its orbit round the earth, till it was entirely overcome.

We have also endeavoured to show that the maintenance of the revolution of the earth, and other planetary bodies, in their present orbits round the sun, is principally dependent upon the same cause, as that which produces, and maintains, their rotation on their axes, viz. the unequal repulsion exerted by the sun towards the hemispheres to the east and west of the meridian where he is vertical, according as they are unequally heated. To this opinion it may be objected, that the acquired centrifugal velocity of the earth, as well as that of other planets in their orbits, acting in conjunction with a constant centripetal force, is sufficient of itself to perpetuate for ever their present orbitual velocity, without any farther assistance. Though the earth and other planetary bodies revolve in elliptical orbits, yet, as their centrifugal velocity must be as much accelerated while they are approaching, as it is retarded while they are receding from the sun; it matters not whether planets revolve in elliptical or circular orbits. The direction of the acquired centrifugal velocity of a planet moving in a circular orbit, is, at every part thereof, acting at an exact right angle to the centripetal force; and in an elliptical orbit, on an average at an exact right angle. Hence it is obvious, that the centripetal force, on an average, can neither accelerate, nor retard, the centrifugal velocity of planets in their orbits; and, therefore, no constantly-impelling force is required, to perpetuate the orbitual revolutions of planetary bodies.

In answer to the preceding objection, it may be remarked, that it supposes, in the first place, there is no resisting medium; for if there is, it is manifest, that the orbitual movements of all planetary bodies must be gradually suspended thereby, unless there be a constant impelling force sufficient to maintain the existing velocity. As I am rather inclined to think, after examining the evidence for and against, that there is no resisting medium, we need not farther insist upon this point.

The objection, in the second place, supposes there is only an attractive, and no repellent force, subsisting between the sun and planetary bodies. The existence of an attractive force subsisting between the sun and planetary bodies, is chiefly known to us by the phenomena of the tides; and by the acceleration of celestial bodies while approaching the sun, and their retardation when receding from it. But the existence of a repellent force, acting as an indispensable auxiliary in the production and maintenance of planetary motion, is in a great measure concealed from observation, by the universal preponderance of the attractive. Still, however, we have evidence of its existence, either exhibited in, or deducible from, a variety of phenomena. 1*st*. The land and water composing the earth's surface absorb caloric, and become warmer and more expanded during day, with greater rapidity, according as the sun exerts a more vertical influence. This fact cannot be explained, without admitting, that the sun exerts a repellent force towards terrestrial caloric. 2*d*. The tails of comets, both in approaching and in receding from their perihelion, are always turned away from the sun. This fact also indicates that a repellent force is exerted towards them by the sun. 3*d*. The rotation of planets on their axes, cannot be explained, without the supposition of a repellent force unequally exerted towards their different hemispheres by the sun, according as they become unequally heated. And the fact of the velocity of their rotation increasing with their distance from the sun, and according as their velocity in their orbits diminishes, demonstrates, that their rotatory velocity is produced, and regulated, by some cause totally different from attraction. 4*th*. From the evidence we previously adduced, we know that the particles of caloric are mutually repellent. Now, if we suppose that caloric also exists in the sun, we infer that it must exert a repellent force towards caloric contained in the earth; because no reason can be assigned, why particles that attract each other, should do so at every distance, while those that repel each other, should not possess a similar unbounded influence.

If the preceding briefly stated reasons afford sufficient evidence for believing, that the sun exerts a repellent, as well as an attractive force, towards planetary bodies; it follows, that the orbitual velocity of planets ought to be regarded in no other light, than as the conjoint result of the continued influence, for an indefinite period, of two equally constant forces, (viz. an attractive and a repulsive force,) acting, not diametrically in opposition to each other, but always at an angle much greater than a right angle. Supposing the attractive force which the sun exerts towards any planet were instantaneously to cease, while the acquired velocity, and the repulsive force exerted towards it by the sun continued; the planet, instead of receding from the sun in a line at a tangent to the orbit when the attractive force ceased, (as would be the case if no repellent force existed,) would fly off from the sun, in obedience to the conjoint influence of the acquired velocity, and the repellent force exerted towards it by the sun, at a greater angle than that formed by a tangent to the orbit. The circumstance, therefore, of the attractive and repellent forces acting not diametrically in opposition to each other, but always at an angle much greater than a right angle, demonstrates that these two forces are constantly restraining and counteracting each other; and accordingly, that a constant impelling force is necessary to maintain planets in their present orbits, and to perpetuate their existing orbitual velocities.

I can foresee, that the circumstance of the commonly received theory affording an explanation of the phenomena presented by the orbitual revolution of planetary bodies, will, with all superficial thinkers, prove the chief obstacle to the reception of any new one. But let it be remarked, that an explanation may not be true, however long and universally it may have been received. Before atmospheric pressure was known, the reason assigned for water following the piston in a water-pump, viz. that nature abhorred a vacuum, was long and universally received, as a sufficient explanation of the fact. And when it was subsequently found that the water would not follow the piston beyond the height of 33 feet, Galileo, who was asked the reason of this, modified the explanation to suit the fact, and said that nature abhorred a vacuum only to the height of 33 feet. But both the original explanation, and the subsequent modification of it, are erroneous. Now, in reality, there is no more reason for believing, that the centrifugal velocity of planetary bodies in their orbits, owes its existence to original impulse, than there was for believing, in the other case, that nature abhorred a vacuum.

Both explanations seem to have been adopted for want of better, solely on the ground of convenience. Both are mere assumptions, resting on no evidence whatever; and instead of being supported, are actually contradicted by every thing analogous in nature.

Again, it may be objected to the cause we have assigned for the centrifugal velocity of planets in their orbits, that it does not seem commensurate with the effect produced. Thus the earth's velocity in its orbit is 68,080 miles an hour, and that of Mercury is 109,400. Now, it can hardly be conceived that orbitual velocities so great as these, could be communicated by a slight degree of unequal repulsion exerted by the sun, towards the different hemispheres to the east and west of the meridian, where that luminary is vertical. In answer to this objection it may be repeated, that, as it is only permitted to man to observe existing phenomena; but not to contemplate either their beginning or their end; planets ought to be considered in no other light, than as moving with the finite velocity resulting from the continued influence of two partly opposing forces, for an indefinite length of time. Besides, our notions regarding the proportion subsisting between velocities, and the forces necessary to produce them, are formed upon the observation of the velocity of bodies, obstructed by the resistance of the atmosphere. Whereas, to have enabled us to judge correctly on the subject, they ought to have been formed upon the contemplation of the velocity of bodies moving through space, in which there was no resisting medium to obstruct their motion. "Newton," says Professor Playfair, "calculates the mean force by which the sun diminishes the force of gravity at the earth's surface, as equal to a 12,868,200th part of gravity." Of course, if a body weighed 12,868,200 lbs. at the earth's surface, the sun's attraction vertically exerted, would only diminish its weight to the small extent of one pound. Now, if we consider that this small force exerted by the sun upon the materials composing the earth, would be sufficient, were the centrifugal force suspended, to carry the earth to the sun through the space of 95,000,000 of miles in about 64½ days; it does not seem surprising, that the cause we have assigned for the centrifugal velocity of planetary bodies, continued for an indefinite length of time, should have been able to communicate their existing orbitual velocities.

In conclusion, whether the explanations given in the preceding pages, of the nature, and causes of planetary motion, be correct or not, I have no hesitation in expressing my belief, that the structure and arrangement of the universe, and the unceasing movements of its different parts, are determined, maintained, and regulated, solely by mutual attractive and repulsive properties, originally and permanently conferred upon its constituent materials. Nothing is either arbitrary, or the result of chance; but every effect naturally results from an adequate cause. The various kinds of ponderable and imponderable materials seem to have been created in such due proportion to each other, that by the mutual action and reaction of their inherent attractive and repulsive properties, the whole moving machinery of the universe is governed by self-adjusting and compensating principles, which insure its permanent stability. Analogy pervades the works of creation. Sameness, or similarity of cause, begets corresponding sameness, or similarity of effect; and wherever this relation seems departed from, it is to be ascribed, not to any actual deviation from the original, and unaltered ordinations of Providence; but to our want of knowledge, and the imperfection of our perceptive faculties, which frequently disqualify us for perceiving resemblances, and the necessary connection that always subsists between cause and effect. The ponderable and imponderable materials of the universe, mutually acting according to their permanently inherent attractive and repulsive properties, constitute what is called Nature; the various appearances presented are Natural Phenomena; and brief descriptions of these, so generalized as to assist our limited faculties, are denominated Nature's Laws. God created Nature. Universal analogy and simplicity in design, combined with infinite variety, and fitness to accomplish every useful end by the most simple means, constitute its characteristic features. Creative wisdom and power are displayed, not as is commonly supposed in forming a temporary world, that without constant superintendence would soon become a wreck of ruin and desolation; but in calling into being a universe at once so perfect, and independent of farther assistance, or interference on the part of its Author, that time can neither impair its structure, nor derange, or suspend its movements.

NEW VIEWS
REGARDING THE
RADIATION OF HEAT,
PRECEDED BY A
REFUTATION OF EXISTING NOTIONS ON THAT SUBJECT.

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SECTION XXII.

REFUTATION OF THE COMMONLY RECEIVED PROJECTILE THEORY OF THE SOLAR RADIATION OF HEAT.

The Sun has been ascertained by astronomers to be a globe, whose diameter is 883,246 miles, and estimated to contain about 333,928 times as much matter as the Earth. Judging from the small attractive influence which it exerts upon planetary bodies relative to its bulk, it has been calculated that its density is only about one-fourth of that of the earth, or one-fifth of that of the moon.

Reckoning the density of water =	1
The density of the Sun is, .	$1\frac{2}{15}$
The density of the Earth, . .	4½
The density of the Moon, .	5½

Regarding the manner in which the sun communicates warmth to the earth, two different theories exist. Agreeably to the prevailing theory, caloric and light are material substances, constantly emanating in straight lines from the sun, in every direction, with the same velocity, viz. about 195,000 miles in a second. The heat, accordingly, which we experience in the solar ray, is supposed to be the effect of caloric reaching us, which left the sun only about eight minutes before, and which has travelled, in that short time, no less a distance than 95,000,000 of miles. The objections to this theory are the following.

1*st*. The incredible velocity (viz. 195,000 miles in a second,) with which radiant caloric is said to emanate from the sun, together with the difficulty of conceiving, how any material substance, moving with such velocity, can strike against bodies, and yet communicate no perceptible impulse.

2*d*. The difficulty of assigning a satisfactory reason for the perpetual emanation of caloric from the sun, even with any degree of velocity whatever.

3*d*. The still greater difficulty of explaining how caloric should continue, at all times, to emanate from the sun with the same degree of intensity; or why the calorific resources of the sun, so long subjected to such consumptive emanation, should not show symptoms of diminution, and exhaustion.

4*th*. The difficulty of perceiving any mechanical, or chemical principle, by which the caloric supposed to emanate from the sun, can be returned to it again; or of showing how the sun can be supplied with caloric from any other source, so as to be able to perpetuate an equal emanation of heat by radiation at all times.

The mere statement of these objections to the commonly received theory, regarding the radiation of heat from the sun, (and which are equally applicable to the radiation of light,) is so obviously subversive of all claim it can have to probability, as to render any lengthened comment unnecessary. To suppose that particles of caloric, and of light, upon their separation either from the sun, or from hot or luminous bodies, should instantaneously acquire a power of moving in straight lines, with a velocity of 195,000 miles in a second; that they should bound all at once from a state of rest into such rapid motion; and that, however strong or weak the impelling force, they should be unsusceptible of moving either faster or slower; is quite preposterous, and totally incompatible with any known principle of motion, resulting either from mechanical or chemical impulse, by which bodies can be affected. And even to suppose that material substances can be moving with such inconceivable velocity, and yet communicate no perceptible impulse to bodies against which they impinge, is a very improbable supposition.

But though we were to admit the possibility of caloric moving at the rate of 195,000 miles in a second, and its incapability of moving either faster or slower, (though such an admission is in direct contradiction to the mechanical law, that velocities are proportional to the forces which produce them;) we would still be puzzled to discover, by what force, such rapid motion, and determinate velocity, could be communicated. If we suppose that the moving force is repulsion amongst its own particles, the supposition necessarily presupposes, that a greater amount of caloric is concentrated around the sun, than the ponderable matter it contains can hold in affinity; and here we are still left with the difficulty of explaining, how such a concentration of caloric could take place.

But even were we to admit, for the sake of argument, that a greater amount of caloric has by some unknown force been accumulated around the sun, than it can retain in affinity; we would still have to contend with the greater difficulty of explaining, how it could continue to emanate equably, and unceasingly from the sun, for thousands of years, without diminishing in quantity, or showing some symptoms of its surplus becoming exhausted. If we conceive that there exists in the sun a repulsive force so powerful, as to cause caloric to separate from it, with a moving velocity of 195,000 miles in a second; and at the same time bear in mind the immense quantity of caloric, that this supposed force, in the course of a few hours, throws upon the earth, which, as seen from the sun at the distance of 95,000,000 of miles, is but a mere point in the celestial circumference; it would be most extravagant, and absurd, to imagine that any surplus of caloric, however great, could long withstand such an exhausting drain, without showing symptoms of diminution.

Provided it be said that all the caloric, or as much caloric, whether it be the same or not, as that which radiates from the sun, returns to it again, so that it is thereby enabled to perpetuate an equal emanation at all times; the difficulty of explaining the mechanical or chemical principle, by which its return can be effected, presents itself. If Prevost's theory of the radiation of heat be adduced in order to supply the defect, I answer, that if that theory be examined upon mechanical principles, which we will now do, it appears palpably absurd; and it is physically impossible that it can be true.

Refutation of Prevost's theory of radiation.—According to Prevost's theory, which Dr. Thomson, in his work on Heat and Electricity, says has been generally adopted, radiation consists in a rapid projectile motion of the particles of caloric. He supposes that bodies at all temperatures radiate caloric, without regard to their being hotter, or colder, than those by which they are surrounded; or in other words, that a mutual interchange of caloric is constantly taking place between bodies, whether their temperature be alike, or different. But as the amount radiated in a given time from any body, increases in proportion as its temperature becomes higher; there is a constant tendency towards the establishment of equality of temperature, by means of radiation.

Now, this theory of Prevost's is defective, in so far as it requires us to admit, that particles of caloric are mutually projected between bodies with inconceivable velocity, without the aid of any impelling force whatever; or at all events, without showing by what force this interchange is accomplished. If it be said, that repulsion, mutually subsisting between the particles of caloric, is the cause of this mutual projection of heat between bodies, the theory is liable to the following insuperable objections. It requires us, without evidence, and in direct contradiction to the laws of motion and rest, to believe that particles of caloric instantaneously assume a rapid projectile movement, in straight lines, by means of repulsion, when the repelling force that resists the motion is equal to that which begets it, (for this is the case when equality of temperature prevails;) and even to believe, that they move in opposition to the preponderance of calorific pressure, for this mechanical impossibility is implied, in the idea of heat radiating from cold towards hot bodies.

When uniformity of temperature among bodies and spaces is established, the mutual repulsion subsisting between the particles of caloric in any given body or space, is precisely balanced by the mutual repulsion of the calorific particles in every surrounding body or space. This state of calorific equilibrium, is necessarily a state of rest, for caloric can no more set itself in motion without being impelled by some force, than any other material substance; and as little can caloric, subjected to forces on every side, originate motion, unless a preponderance, either of impulse or of resistance, exist in one direction or another. Upon a similar principle, it is mechanically impossible for the particles of caloric in a body that is colder than the air, and all other surrounding substances, to project themselves in straight lines by means of repulsion, in opposition to a stronger repelling calorific force exerted upon them on every side. Mutually repellent particles of caloric, in obedience to the preponderance of calorific repulsion, can only move by conduction, or radiation, in one direction, viz. from hot towards relatively cold bodies; and it is manifestly absurd to suppose, that, when caloric radiates in one direction, in obedience to the preponderance of calorific repulsion, it can simultaneously radiate in the opposite, which would be contrary to the preponderance of calorific repulsion.

Besides, this theory of Prevost's is entirely imaginary. There is not the slightest evidence, that caloric radiates between bodies whose temperature is precisely the same; and still less is there evidence, that it radiates from cold towards hot bodies, in any quantity, however small. If such were the case, contiguous bodies whose surfaces varied in fitness for radiating caloric, if partially exposed to a view of the sky, from which there could be no radiating return, could never arrive at an equality of temperature, however well and long established the calorific equilibrium might be. In such circumstances, those which had the best radiating surfaces would be uniformly the coldest. Whereas, nothing is more certain, than that the temperature of all contiguous bodies soon becomes alike, when temperature is neither upon the increase, nor the decrease. And the best radiators of caloric are only found to be colder or hotter than surrounding bodies, when temperature is either sinking or rising; and this effect necessarily results from their property of radiating caloric, and absorbing it, or, in other words, of cooling and heating faster than other bodies, when a change of temperature is taking place.

The preceding refutation of Prevost's theory, demonstrates its unfitness to obviate the objections we advanced to the projectile theory of solar radiation. And we again repeat, that if caloric be continually projected from the sun, in the quantity, and with the velocity, which that theory supposes, no mechanical or chemical principle can be pointed out, by which its return can be effected. The same repellent force which causes caloric to emanate from the sun, must effectually prevent its return; and we can fancy no exhaustless source from whence it can be supplied.

SECTION XXIII.

REFUTATION OF THE VIBRATORY THEORY OF THE RADIATION OF HEAT.

According to the other theory of the solar radiation of heat, no emanation of any material substance from the sun takes place. It considers heat, like gravity, to be merely a quality of matter, consisting in a peculiar vibration, or undulation, to which the particles of material substances are continually more or less subjected; and which the sun, and heated bodies, are capable of exciting.

Dr. Young, one of the ablest advocates for the immateriality of heat, supposes, that it is presented in two conditions, the vibratory or permanent, and the undulatory or transient. Vibratory heat, according to this hypothesis, is a motion to which all material substances are liable, and which is more or less permanent; and undulatory heat, is this motion propagated like a wave through a diaphonous medium, and which, like light, (to which, both in its states and movements, it is analogous,) is susceptible in its progress of reflection, and separate refraction. The expansion, the softness, the fluidity, and the vaporization of bodies, according to this theory, are results, not of their combination with a material substance which we call caloric, but of different degrees of vibration among their component particles.

This theory labours under a great many insurmountable objections. It explains the phenomena of expansion, softness, fluidity, gaseity, and all others connected with temperature, so very imperfectly, that it is difficult to perceive, how they should be considered to be explained by it at all. It gives no information how vibration among the particles of bodies originates; how it diminishes and increases in intensity, in accordance with the uncertain and irregular variations of temperature; how it can be communicated through a Torricellian vacuum; or how it can perpetuate its oscillations without diminution, in opposition to the pressure of superincumbent strata of ponderable materials, gravitating towards the centre of the earth. Besides, the theory itself is built upon a foundation that is entirely visionary. There is not even the shadow of evidence, that the particles of bodies around us are in constant vibration; nor is there the slightest resemblance between vibration, and the effects ascribed to caloric. Indeed, the only reason for the belief that heat and temperature consist in the vibration of the particles of bodies, rests upon an unwarrantable inference, deduced from the difficulty of accounting for the development of heat by friction. And even the fact, admitted by supporters of the vibratory theory, viz. that less heat is evolved when bodies subjected to friction are surrounded by bad conductors of caloric, proves, that the heat which makes its appearance is not created, but is merely collected from external bodies, and accumulated by friction. In reality, the agency of friction in evolving caloric, seems to depend on some unknown influence it exerts, in drawing supplies of caloric from external bodies, by occasioning calorific currents to pass through the best conducting channels, and probably through the substance towards the surface of the bodies subjected to friction, where it is thereby evolved.

The vibratory theory is likewise unphilosophical. Motion is not, and cannot be, a quality of matter, consistent with the universally received doctrines, that inanimate matter is equally indifferent to motion and rest; that a body at rest cannot set itself in motion, because it can have no inherent tendency to move in one direction more than in any other; and that a body in motion cannot of itself increase or diminish its velocity; nor suspend its motion; nor alter the direction thereof. If we believe in the vibratory theory of heat, we must reject these doctrines; for in accordance with the uncertain and irregular variations of temperature, we would have to admit that the particles of bodies, instead of being indifferent to motion and rest, are in a state of constant motion. We would also have to admit, that they possess an inherent power of changing their motion from one direction to the opposite, for vibration implies such opposite movements; and that, contrary to established mechanical principles, they have likewise within themselves an inherent power of increasing, and diminishing, the velocity, or the extent, of their oscillations, (such being the only meanings attachable to what is called intensity of vibration;) for otherwise, how is it possible, by the vibratory theory, to account for the irregularities with which mercury and all other substances, expand and contract, not only when in immediate contact with surrounding ponderable materials, but even when separated almost entirely from them, by suspension in a Torricellian vacuum?

Motion, whether vibratory or undulatory, presupposes a force to produce it; and when communicated to ponderable materials around us, is observed gradually to subside, in consequence of their universal gravitation towards the centre of the earth. Accordingly, when it has diminished, it never afterwards of itself begins to increase; and in like manner, when it has ceased altogether, it never re-commences of its own accord. Temperature, on the contrary, as indicated by a thermometer, even though enclosed in a Torricellian vacuum, exhibits every species of irregularity. It rises; it sinks; it remains stationary; it fluctuates with different degrees of rapidity at different times; it may be made to sink suddenly, and to a great extent, by immersion in a freezing mixture; and to rise by exposure to the heat of a fire, or of the sun; or by immersion in a hot liquid. And these variations of temperature, are effected by means calculated neither to produce, increase, diminish, nor continue, vibratory movements among the particles of bodies.

Analogical reasoning likewise disproves the vibratory theory. Sound is an effect perceived by our sense of hearing, and is known to result from impulse imparted to elastic bodies, and propagated to a distance, and communicated to our auditory apparatus, in the form of vibratory undulations of air, or other elastic media. Sonorous vibrations, however, unless renewed by repeating the impulse, soon cease. And judging from the rapid diminution of sound from the instant that impulse is imparted to a sonorous body, (however well calculated to perpetuate vibration,) and also according as we happen to be more distant from it; we infer, that the vibratory oscillations which generate sound, diminish successively from the instant that impulse is communicated; and that a less degree of oscillation is imparted to each stratum of particles, according as they recede from that to which it was first communicated. Now, if heat consist in the vibratory movements of the particles of bodies, in what peculiarity can the vibrations of aerial particles which produce sound, differ from those which, according to the vibratory theory, produce heat? Why should the former last but an instant, and the latter continue for ever? Why does not sound and heat always exist proportionally to each other? Why does not the vibration of a drum, and of an Indian gong, produce heat in proportion to their noise? And why does the fire burn, and the sun shine in silence?

Again, it has been ascertained by experiment, that a thermometer placed in a Torricellian vacuum, corresponds in its risings and sinkings with one suspended contiguously in the external atmosphere. It has been also ascertained that the sound of a bell rung in the receiver of an air-pump, diminishes gradually as the air around it is withdrawn, and at length ceases to be heard altogether: immediately, however, upon the re-admission of air, it again becomes audible. The former of these experiments proves that heat can pervade a vacuum; the latter, that vibrations cannot. Hence we infer that heat and vibration cannot be identical.

Finally, it has been ascertained that the earth, at the depth of forty feet below its surface, undergoes no variation of temperature throughout the year: and water issuing from the ground at that depth, indicates at all seasons the mean annual temperature of the place. It also appears from a variety of observations made in different quarters of the world, that below the depth of forty feet, the temperature increases at the mean rate of about 1 degree of Fahrenheit for every fifty feet of farther descent. Now, as all ponderable materials around us are constantly gravitating towards the earth's centre; it is physically impossible, upon mechanical principles, that vibration among the particles of bodies, whether existing in the solid, liquid, or gaseous state, can perpetuate itself, in opposition to the weight of superincumbent strata, so as to explain the constant uniformity of temperature at the depth of forty feet. And it is more palpably a physical impossibility, that the velocity, or the extent of the oscillations, can increase, in opposition to the augmenting weight of superincumbent strata, so as to account for the gradual and permanent augmentation of temperature, as we descend farther int the earth. Though no other argument could b adduced against the vibratory theory, this alone more than sufficient to disprove it, were the eviden in its support fifty times stronger than it is. T notion, therefore, that the sun communicates warmth to the earth by exciting vibration among the particles of bodies, being founded upon a false view of the nature of heat, must be considered entirely erroneous and inadmissible.

Having thus brought forward a sufficiency of objections to show that both the theories at present entertained regarding the nature of the solar radiation of heat, are altogether unsatisfactory, and inadmissible, we will now proceed to advance a new theory as a substitute for those we have been endeavouring to refute. Before doing so, however, it may be necessary here to introduce some preliminary remarks on the nature of caloric, and the mode in which its transference by radiation, from one body to others in its immediate vicinity, takes place. These, it is hoped, will tend not only to elucidate and confirm our subsequent observations, but by affording an opportunity of proving our statements as we proceed, objections to our theory will be thereby anticipated and obviated.

SECTION XXIV.

ON THE NATURE AND PROPERTIES OF CALORIC.

Caloric, commonly called heat, appears to be a material substance, whose particles are mutually repellent, while they are attracted by all ponderable bodies; and different ponderable materials seem to exert towards it different degrees of attractive force. Its existence is only known to us by its effects. The chief of these are: its imparting to the sentient portion of our frame the sensation of warmth; and its power of increasing the separation of the particles of bodies, and thereby expanding and decomposing them, and altering their states from solids to liquids, and from liquids to vapours and gases.

The principal proofs of the materiality of heat briefly stated, are: its power in expanding bodies by separating their particles, and giving increased resistance to compression; its communicating to our frame the sensation of heat; its influence in decomposing and altering the appearance of bodies subjected to its concentrated action; its absorption and disappearance when bodies are converted from the solid to the liquid, or from the liquid to the gaseous state; and its evolution and re-appearance upon their being re-converted; its susceptibility of being evolved, or partially expelled from bodies by condensation, whether effected by mechanical pressure or by chemical combination; its consequent capability of being transferred from one body to another; its reflexibility, and its refrangibility. These phenomena only admit of a satisfactory explanation, upon the supposition that caloric is a material substance whose particles are mutually repellent, while they are attracted by those of all ponderable bodies. The following evidence of the attractive and repulsive properties of caloric has been already given; but to save references, may be here repeated.

That the particles of caloric are mutually repellent, may be inferred from the following circumstances: 1*st.* They are never found cohering, or aggregated, so as to present a body possessed of sensible magnitude. 2*d.* Though an accumulation of caloric may be artificially concentrated at any given place; still, it is ever tending to diffuse, and distribute itself, according to the laws that regulate the equalization of temperature. 3*d.* The distribution of caloric around us is such, or is ever tending thereto, that heating bodies does not materially increase, nor detract from their weight. From these circumstances, severally and conjointly, it may be inferred as probable, that a repellent force mutually subsists between the particles of caloric. The truth of the inference, however, is satisfactorily demonstrated by the following experiment.

If a bladder half inflated, be placed in the receiver of an air-pump, it will gradually expand as the air around it is withdrawn; and again contract upon its re-admission. This experiment shows that some repellent property exists in a state of union with the aerial particles. And that this property resides in the caloric held in affinity by the aerial particles, is evident from the fact, that the half inflated bladder expands with the rising, and contracts with the sinking of temperature, just as it does with increase and diminution of external atmospheric pressure, upon the withdrawal, and re-admission of the air around it, by means of the air-pump. That the caloric absorbed by bodies upon being heated, does not actually fill the additional space occupied by their expansion, is obvious from the circumstance of different substances undergoing very different degrees of expansion, upon absorbing similar amounts of caloric. The same truth is also evident from the expansibility of even the same substance, varying with difference of temperature: liquids, for instance, become more expansible as they approach their boiling heat.

That attraction mutually subsists between caloric and ponderable materials, is established by the fact ascertained by Dr. Crawford, that atmospheric air of the usual density has a greater capacity for caloric than a vacuum. This could not be the case, unless an attractive force subsisted between caloric and aerial particles, so as in part to counteract the tendency of caloric to diffuse itself equally throughout space, by means of its repellent property. The same truth is demonstrated, by the unequal capacities for caloric of similar bulks of all different substances. Thus, water has a greater capacity for caloric than an equal bulk of any solid or liquid substance known; and even a greater capacity than atmospheric air, not only when estimated by bulk, but also when estimated by weight.

That different ponderable substances exert different degrees of attractive force for caloric, may be inferred as probable, from the remarkable difference in the density of bodies at similar temperatures. A similar inference may be deduced from the want of any strict relation between the densities of bodies, and their capacities for caloric, as is strikingly exemplified in the case above alluded to, of the calorific capacity of water compared to that of other substances. Besides, it is owing to the different degrees of attractive force which different substances exert towards caloric, that equality of temperature does not consist in an equal distribution of caloric among contiguous bodies, but in a distribution proportioned to their different capacities for retaining it in affinity.

SECTION XXV.

NEW VIEWS REGARDING THE MANNER IN WHICH CALORIC RADIATES FROM HOT TOWARDS RELATIVELY COLD BODIES.

The real nature of the radiation of heat, or in other words, the mode in which a heated body transmits caloric through a vacuum, or through gaseous substances, so as instantaneously to communicate warmth to any opaque body at a distance, will appear sufficiently obvious, if we reflect upon the refutation previously given to Prevost's theory. Upon the introduction of any body whose temperature is higher than that of the circumambient air, the calorific equilibrium is destroyed; and caloric distributed around, whether near or distant, being pressed by a stronger repulsive force from the heated body, than it is towards it, instantly, in obedience to the preponderance of calorific pressure, begins to move from the heated body. And *vice versa*, when any substance is introduced at a lower temperature than the surrounding atmosphere, and bodies therein distributed, caloric, in obedience to the preponderance of calorific repulsion, flows towards it, until equality of temperature, in which the calorific equilibrium consists, is established. The radiation of heat, however, does not consist, as is usually supposed, in particles of caloric darting from the heated body in straight lines, with inconceivable velocity, until they reach some opaque substance that intercepts their progress; but in the excess of caloric in the heated body instantaneously exerting, and propagating with inconceivable velocity, an increased repulsive force to surrounding caloric, and thereby communicating to it a slow receding motion from the heated body. The repulsive force being greatest at the surface of the heated body, the velocity with which the particles of caloric recede from it, is also greatest there. And, agreeably to the law of distance, the impulse, and receding velocity, communicated to surrounding caloric, by the excess of calorific repulsion in the heated body, must diminish as the square of the distance from the heated body increases.

When a receding movement from a heated body is communicated to surrounding caloric, the nearest particles to any opaque body that intercepts radiation, must necessarily be the first in the receding calorific stream, to come in contact with it; and by uniting with it, to communicate expansion and increase of temperature. Of course, when we feel the radiant heat of a distant fire, the sensation is not produced, as is usually supposed, by the identical particles of caloric which had that instant separated from the fire; but by those previously most contiguous to our organs of sense, entering, and combining with them.

From the preceding observations, it is obvious, that the rapid transmission of the warming influence of a heated body by radiation, differs essentially from the manner in which sonorous vibration, agreeably to the vibratory theory of heat, is propagated through air. Sound is conveyed through the atmosphere by means of a successive chain of aerial oscillations, communicated onwards from one stratum of particles to another, so as to travel at the rate of 1142 feet in a second; whereas heat radiates with infinitely greater velocity, by propagating, through the instrumentality of repulsion subsisting between particles of caloric, merely a preponderating calorific pressure; and consequently, by propagating to a distance with equal velocity, a comparatively slow receding motion to caloric, which may be either reflected or refracted. The motion of aerial particles in transmitting sound is undulatory, and not progressive; whereas, that of calorific particles, in transmitting heat by radiation, whether undulatory or not, (though it is probably neither undulatory nor vibratory,) is always accompanied with progression. Accordingly, when aerial particles, whose vibrations produce sound, have ceased to vibrate, in consequence of their own weight, and the counteracting resistance of incumbent and surrounding strata of ponderable materials, they occupy precisely their former positions. Whereas, before radiation ceases, a portion of the particles of caloric must have separated from the heated body, and receded from it, and driven surrounding calorific particles before them, to the distance necessary to effect such a dispersion, and distribution of caloric, as restores the calorific equilibrium.

The tendency of caloric to restore and maintain an equilibrium of tension, does not admit of any vacuity in the calorific radiating stream. Consequently, the propagation of the preponderating calorific pressure which constitutes radiation, may be instantaneously interrupted by the interposition of any screen, which, by preventing the passage of caloric through it in the form of radiation, divides the radiating stream. In short, the propagation of the preponderating calorific pressure constituting radiation from hot to cold bodies, cannot go on, unless it be accompanied with the separation of heat from the heated body, and a receding motion so far as radiation extends, by all caloric distributed around the heated body, so as precisely to make room for the amount of dispersing caloric that separates from it. And thus, though the progressive motion with which the preponderating calorific pressure, and the accompanying transmission of a receding calorific movement are propagated, be inconceivably rapid, and agreeably to the isochronal principle of transmission by oscillation, uniform in velocity, whatever be the degree of preponderating impulse, or the distance from its source; the progressive velocity of the radiating caloric itself is comparatively very slow, and diminishes with the degree of preponderating impulse, and also as the square of the distance from its source increases. In short, the velocity of a radiating calorific stream, and the amount of heat communicated thereby, in a given time, to a distant body, supposed for the sake of perspicuity to absorb the whole of it, will be proportional to the amount of caloric which separates by radiation from the visible side of the heated body in that time, divided by the square of the distance. And this result will likewise be greater or less, not only in proportion to the superior warmth of the heated body, but also according to the facility with which its surface radiates caloric.

The preceding view of the manner in which caloric radiates from hot towards relatively cold bodies, refutes the almost universally received opinion of radiant caloric moving with an inconceivably rapid projectile velocity, by affording a simpler, and a more rational explanation of the phenomenon. It is no vague hypothesis. It is founded upon the acknowledged existence of a repellent force mutually subsisting between calorific particles; and forms, as it were, a natural, and even a necessary deduction therefrom. Calorific particles, in consequence of being mutually repellent, tend to distribute themselves at equal distances from each other; and whether in a state of motion or rest, their relative positions must, from the same circumstance, be in some degree preserved. Hence, when a greater amount of calorific particles are concentrated in one body or space, than exists in surrounding bodies or spaces, considered in relation to their different capacities for caloric, it is absurd to suppose, and even mechanically impossible, that an inconceivable velocity can be thereby communicated to particles, separating gradually, and successively, as the slowness in the cooling process indicates; so that from a state of rest, they are instantaneously projected through the atmosphere to the greatest distance, without imparting any receding movement to calorific particles therein distributed, or sustaining from their repulsion the slightest resistance, or interruption. And it is equally impossible, upon mechanical principles, that particles so projected, can move with the same velocity, whether the excess of caloric, or in other words, whether the preponderance of repellent force by which their motion is occasioned, be great or small; or that they can move with equal velocity at every distance from the source of motion.*

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* Upon looking into Dr. Murray's System of Chemistry, I find that the above theory of calorific radiation from hot to relatively cold bodies, corresponds, in part at least, with that of Pictet of Geneva. As I have not seen Pictet's writings, I

The only other inquiry we mean to institute in this Section, is regarding the proportion of caloric that radiates. For instance, when caloric radiates through the atmosphere from a hot to a cold surface, does the whole caloric distributed in the intermediate atmosphere partake of the progressive movement, or only a part of it? After reflecting upon various radiating phenomena, especially those connected with combustion, I am led to conclude, that only a

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am ignorant how far the two theories correspond. From the brief abstract, however, given by Dr. Murray, it appears that Pictet's theory, and the one we have proposed, agree in the following particulars, viz. that so long as equality of temperature amongst neighbouring bodies subsists, caloric may be considered as distributed amongst them in a state of equal tension or elasticity; and so long as this state continues, no radiation takes place between them; and they also agree in the direction in which radiant caloric moves, viz. only from hot towards cold bodies. But I do not know whether Pictet adopts the common opinion, that the radiation of caloric consists in an inconceivably rapid projection of calorific particles from the hot to the cold body, (though from certain expressions used, I rather conceive he does;) or whether his theory corresponds with the one we have advanced, viz. that radiant caloric never moves but with extremely little velocity in comparison with what is usually imagined; that it moves with different degrees of velocity, according to the strength of the impulse, and diminishes in velocity as the square of the distance from the source of motion increases; and that the inconceivable velocity with which caloric has been supposed to travel by radiation, is merely a propagation of the preponderance of calorific repulsion, and in obedience thereto, a slow receding motion by all caloric exposed to the preponderating impulse.

portion of the caloric distributed amongst gaseous particles radiates. The following supposed cases will show the difficulty of explaining the phenomena otherwise.

If the ponderable bases of gaseous particles be merely mixed with caloric, without being chemically united with, or attached by affinity to any portion thereof, they should be floated in all directions from a fire, along with the radiating calorific stream, just as light bodies diffused, or substances dissolved in water, are carried along with the current. This, however, appears not to be always the case. We find, for instance, that in those directions from whence air is supplied in order to combustion, caloric radiates from the fire in opposition to the current of air. Again, if the whole caloric contained in the atmosphere were chemically combined therewith, the whole particles, including both their ponderable bases, and the caloric held in affinity, would also, as in the former case, float together during radiation; but this is likewise contradicted by the fact above stated. The only way in which these phenomena can be explained, is by supposing, that only a portion of the caloric contained in the atmosphere, is held in affinity by the aerial particles; while another portion, which may be denominated the intermediate or free caloric, is merely intermingled with the aerial particles, without being held in affinity by them. These portions of caloric may be considered as mutually interchangeable; but so long as they remain distinct, the movement of the former is determined by that of the aerial particles by which it is held in affinity; while the movement of the latter, which is the only portion that radiates, is determined by the preponderance of calorific repulsion exerted upon it, and, consequently, may be simultaneously moving either in the same, or in a contrary direction, to that of the aerial particles with which it is intermingled. As I conceive that caloric exists distributed around the earth to a considerably greater altitude than the aerial atmosphere, in subsequent passages, I mean to include under the term "calorific atmosphere," not only that portion of caloric which we suppose exists beyond the boundary of the aerial atmosphere, but also that portion which, though intermingled with the aerial particles, is not held in immediate affinity by them, but is free to move or radiate in obedience to the preponderance of calorific repulsion.

SECTION XXVI.

A NEW VIEW OF THE SOLAR RADIATION OF HEAT.

PONDERABLE materials, by means of attraction subsisting between their particles, are concentrated into those aggregate revolving masses, which have been denominated suns, stars, planets, satellites, and comets. Were attraction the only force existing in nature, the ponderable, or mutually attractive materials, of each of these celestial orbs, could only exist as solid, cohering, and incompressible masses.

On the other hand, caloric, provided repulsion subsisting between its particles were the only force by which it was actuated, would distribute itself equally throughout unoccupied space. But this force being counteracted by a strong attraction exerted upon it by ponderable materials, its equilibrium and imponderable character, is everywhere maintained, by its being concentrated in the form of an atmosphere around the earth, and probably around all other celestial orbs, and intermixed in due proportion to produce the effect, with the different concentric layers of the ponderable substances of which they are composed. Caloric is not imponderable, in consequence of not being attracted by ponderable matter, (for it possesses that characteristic in a high degree,) but because its particles are also mutually repellent. By means of the conjoint influence of these forces, caloric is enabled to penetrate, and pervade all ponderable materials, and so to intermix with their particles, that the repulsion exerted towards caloric by that which is intermixed, is everywhere an exact counterpoise to the attractive influence which these ponderable materials exert towards it. In each concentric layer of the earth, and of every other sphere, the quantities of caloric distributed, must be proportional to the degree of influence exerted upon it, by the conjoint forces of attraction for ponderable materials, and repulsion subsisting between its own particles, modified by the compression of external strata of ponderable materials gravitating towards the centre of each sphere.

The capacity of all interior strata of ponderable materials for caloric, must be diminished by the weight, or compression, of those that are exterior; while their absolute attraction for it, (which is a constant quantity,) remains undiminished. Hence the reason why the condensed central portions of the earth must exert an unsatisfied attraction upon all surrounding caloric, which must increase the quantity intermixed with the superficial, and less condensed strata of the earth, beyond what their own unassisted attraction for it would be able to retain in immediate affinity. Hence also the reason, why a portion of caloric is retained by attraction around the earth, in the form of an atmosphere. It is likewise probable, that the permanent and progressive rise of temperature experienced in digging perpendicularly into the earth below the depth of forty feet, is the permanent distribution which caloric, under the influence of the various forces to which it is subjected, naturally adopts; and results principally from the capacity of interior strata of ponderable materials for caloric, being diminished by the compression of those that are exterior, while their absolute attraction for it is not thereby lessened.

The intermediate space beyond the boundaries of the calorific atmosphere surrounding the earth and other planetary bodies, is probably an entire vacuity. Our theory of the solar radiation of heat, therefore, supposes, that caloric, and the other imponderable bodies concentrated by the attraction of the ponderable materials of the earth, are never transmitted to any other celestial body; but remain permanently attached to it, during all its revolutionary movements. And in like manner, it also supposes, that the heat and light held in attraction by the ponderable materials of the sun, are never transmitted to any other celestial orb.

In accordance with these views, I conceive, that while the ponderable materials contained in the earth, are attracted by those of the sun; caloric contained in the earth, and concentrated by attraction around it, is repelled by caloric, or some other calorific repelling materials, contained in and concentrated by attraction around the sun. The solar radiation of heat, therefore, as experienced by man, whose place of observation is restricted to the bottom of the aerial and calorific ocean surrounding the globe, is neither more nor less than caloric descending slowly through the atmosphere, and getting absorbed by the land and water on the surface of the earth, produced by the repulsion of caloric, or other calorific repelling materials contained in the sun; and it is only the propagation of this slow receding movement of caloric onwards, that is inconceivably rapid.

As the phenomena of the radiation of heat from and towards the surface of the land and water, is all that we have an opportunity of observing, to avoid circumlocution, in subsequent passages, when we use such phrases as, "radiation of caloric towards, or from the earth," or "the absorption or giving out of caloric by the earth," we are to be understood as referring to the surface of the land and water composing the earth's surface, and not the external surface of the aerial atmosphere surrounding the land and water.

The movement of caloric by radiation either towards, or from the earth, can only result, like the motion of every other material substance, from the influence of some force; or if there be one or more opposing forces, from the preponderance of the one class over the other; and the direction of the motion must ever be towards the restoration of the calorific equilibrium. Now, the forces that directly or indirectly enable caloric to penetrate the crust of the earth, and cause a portion of the calorific atmosphere to be absorbed by land and water during day, are the following.

1*st.* Attraction exerted by the ponderable materials of the earth upon the calorific atmosphere by which they are surrounded.

2*d.* Repulsion exerted by caloric, or other calorific repelling materials, contained either in the sun or other celestial orbs, towards the calorific atmosphere on the side of the earth presented to them.

3*d.* The influence of the sun's attraction during day, in counteracting, and thereby diminishing, (though in a very slight degree,) the weight, or gravitating tendency, of all ponderable materials towards the centre of the earth.

The forces, that, by acting in opposition to those above-mentioned, tend to prevent any farther absorption of the calorific atmosphere, and which, when they happen to preponderate, gradually expel previously absorbed caloric from the surface of the earth, are the following.

1*st.* Attraction, or affinity, mutually subsisting between neighbouring ponderable particles.

2*d.* The weight or pressure of such particles towards the centre of the earth, with which may be included the incumbent weight of all external strata of ponderable materials.

3*d.* The influence of the sun's antipodal attraction during night, in co-operating with, and thereby increasing, (though in a very slight degree,) the weight, or gravitating tendency of all terrestrial ponderable materials towards the centre of the earth.

4*th.* Repulsion exerted by caloric, or other calorific repelling materials previously contained within the earth's surface, towards the calorific atmosphere surrounding the earth.

5*th.* Attraction exerted by the ponderable materials of the sun, or of other celestial orbs, upon the calorific atmosphere on the side of the earth presented to them.

If the conjoint influence of the former class of forces preponderate over that of the latter, the land and water on the surface of the earth, in order to the restoration of the calorific equilibrium, absorb caloric from the surrounding calorific atmosphere; and the phenomena of the radiation of heat towards the earth, and of increasing warmth, are presented. On the contrary, when the conjoint influence of the latter class preponderates over that of the former, caloric, in obedience to the preponderance of pressure, gradually separates from the land and water composing the earth's surface; and again becomes a portion of the calorific atmosphere by which the earth's surface is surrounded; and this constitutes what is called the retrocession, or radiation of heat from the earth. When the two classes of forces exactly balance each other, the calorific atmosphere may be said to be in a state of equilibrium, and neither radiates from, nor towards the land and water composing the earth's surface. And it need scarcely be added, (other things, such as the radiating and absorbing power of the subjacent surface of the earth, being equal,) that according to the degree of preponderance of the one class of forces over the other, so will be the amount of the calorific atmosphere that is absorbed, or given out by the earth in a given time.

We have no means of determining the progressive velocity with which calorific particles, diffused throughout the atmosphere, move onwards by radiation. But while we conceive that the repulsive influence of calorifie repellent materials in the sun, traverses the celestial vacuity with the velocity of light, viz. 195,000 miles in a second, it is by no means improbable, that the actual velocity with which calorific particles distributed throughout the atmosphere, move towards the earth's surface under the influence of a vertical sun; or separate from the earth's surface by radiation, under the most favourable circumstances during night, may never exceed half a mile in the hour.

Such are the leading principles which determine whether the radiating calorific stream shall direct its course from, or towards the earth's surface. We will now proceed to apply them to the explanation of the phenomena of the solar radiation of heat towards the earth, during day, and summer; and of the retrocession of heat by radiation from the earth, in equal quantity, during night, and winter.

From an examination of the two classes of forces which operate upon the calorific atmosphere surrounding the earth, it is obvious, that the equilibrium of the calorific atmosphere must be subjected to a constant cause of disturbance by the earth's diurnal rotation on its axis; and also by its annual revolution in its orbit. Each portion of the earth's surface, during the alternations of day and night, and summer and winter, being successively more or less directly presented to, and turned away from the sun, is alternately absorbing and giving out caloric. During day, the attraction exerted by the ponderable materials of the earth, upon the atmosphere of caloric by which it is surrounded, being aided by the repulsion exerted by the sun towards the terrestrial caloric, as well as by the slightly diminished gravity, or tendency of ponderable materials towards the earth's centre, preponderates over the forces, which prevent any farther absorption of the calorific atmosphere by the earth. Consequently, in obedience to the preponderance of pressure, and in order to the restoration of the calorific equilibrium, the side of the earth presented to the sun absorbs caloric. During night, when the attraction exerted by the ponderable materials of the earth upon the surrounding atmosphere of caloric, ceases to be assisted by the repulsion of that which is concentrated around the sun; and when the amount of caloric contained in the earth is increased by the quantity absorbed during the previous day, the forces which tend to expel caloric from the earth's crust, preponderate over those which enable it to penetrate. And consequently, in order to the restoration of the calorific equilibrium, the side of the earth which is turned away from the sun is always giving out caloric. Such I conceive to be the nature and cause of the solar radiation of heat towards the earth, and of the rise of temperature which we experience during day; and of the corresponding radiation of heat from the earth, and of the sinking of temperature experienced during night.

The equilibrium of the calorific atmosphere, besides being disturbed by the earth's diurnal rotation on its axis, is subjected to a farther cause of periodic disturbance, by its revolution in its orbit. Owing to the inclination of the ecliptic from the plane of the equator, the northern hemisphere is more or less turned towards the sun, and the days are longer than the nights during summer. And, on the contrary, the same hemisphere is turned more or less away from the sun, and the nights are longer than the days during winter. Now, as the influence of the caloric contained in the sun in repelling any portion of the calorific atmosphere, and causing its absorption by the earth, diminishes with the increase in the obliquity with which that force is exerted; it follows, that the sun's influence, in causing radiation of caloric towards any portion of the earth's surface, becomes greater according as he approaches the zenith, and less according as he gets nearer the horizon. During summer, when the sun in northern latitudes is longer above the horizon than below it, and when his influence in causing calorific radiation towards the earth is exerted more perpendicularly than average, the earth absorbs a larger amount of caloric during day, than it gives out during night. On the contrary, during winter, when the circumstances above-mentioned in reference to the sun are reversed, the earth gives out a greater amount of caloric during night, than it absorbs during day. And as the temperature of the incumbent atmosphere, is principally regulated by that of the subjacent earth; the circumstances above-mentioned, explain the cause of the greater warmth experienced during summer, than during winter.

Again, in consequence of the slowness with which the ponderable materials composing the earth's surface increase or diminish in temperature, the maximum diurnal heat does not take place till the sun has somewhat passed its highest meridian altitude. And, for a similar reason, the earth continues to absorb more caloric during day, for some time after the summer solstice, than it parts with during night; and accordingly, the temperature, in northern latitudes, continues to rise for some weeks after the sun has begun to retrograde towards the south. In like manner, when the circumstances during winter are reversed, the temperature continues to sink for several weeks after the winter solstice.

Finally, as the aggregate forces which cause caloric to be absorbed by, or to separate from the earth considered as a whole, (except what difference may arise from the very slight eccentricity of its orbit,) are the same at all times, so must be the aggregate temperature of the earth's surface. What is summer to the northern hemisphere, is winter to the southern; and what is day to the one side of the globe, is night to the opposite. Consequently, while one side of the earth is absorbing caloric, the opposite side is simultaneously parting with it in equal quantity. And thus, though the temperature of each portion of the earth's surface be continually changing; the aggregate temperature of the whole taken together, is always the same.

The transference of caloric, in the course of the year, from one latitude to another, by the influence of the repellent force of the sun, is effected by the tendency of the calorific atmosphere to maintain everywhere an equal, or a nearly equal elevation above the level of the sea, like the aerial atmosphere. The manner in which this is accomplished will be best understood, by supposing, that, instead of the calorific atmosphere, the aerial atmosphere is itself gradually compressed; and that a portion of it is slowly absorbed by the earth, when the sun is above the horizon; and again slowly given out when that luminary is below the horizon. And likewise by supposing that the amount of atmosphere absorbed exceeds that given out during summer, as much as it falls short of it during winter. In that case, the tendency of the aerial atmosphere to maintain a uniform, or a nearly uniform elevation all round the surface of the globe, would cause a diurnal atmospheric tide to follow the path traced by the sun on the earth's surface, during its rotation on its axis. And supposing the absorption of the atmosphere to increase according as the sun's influence is exerted more vertically, the gradual transference of a portion of the aerial atmosphere, during the alternation of summer and winter, from the one hemisphere to the other, would be accomplished in a manner perfectly analogous to that in which we conceive a portion of the calorific atmosphere is transferred.

If the sun had never existed, and the terrestrial caloric had been distributed in obedience to the conjoint influence of repulsion amongst its own particles, and attraction for ponderable substances, modified by the mutual attraction subsisting between all ponderable materials; the proportion of caloric existing in the form of an atmosphere around the earth, would not only have been much greater than it is, but it would have been distributed equally around every part of the earth's surface, (except for the influence of rotation in causing accumulation in the equatorial regions,) and no portion thereof would have been warmer than another. The influence of the sun, therefore, in altering, or modifying the distribution of caloric attached by attraction to the earth, has been, 1*st*, To augment permanently the aggregate amount absorbed by, or intermixed with, the ponderable materials composing the crust of the globe; the additional proportion absorbed, and intermixed therewith, becoming less, according as we recede from the equator towards either pole. 2*d*. To diminish, in like proportion, the amount of caloric surrounding the earth in the form of an atmosphere.

It might be objected to these conclusions, that as the mean temperature of the ponderable materials on the earth's surface is not increasing in any latitude; as much caloric must separate by radiation from its surface during night, as it absorbs during day. And accordingly, that no permanent or considerable alteration in the distribution of the terrestrial caloric, such as exists in the different latitudes of the earth, could be effected by the sun's influence.

In answering this objection, it must be admitted, that the amount of caloric which at present separates from the earth during the nights throughout the year, is exactly equal to the amount absorbed during the days throughout the year. But in estimating the repellent influence of the sun, upon the distribution of caloric permanently attached by attraction to the earth, we ought to consider what would have been its distribution, provided there had been no sun; and how the creation of a sun would affect and alter that distribution. Supposing the terrestrial caloric distributed equally over every latitude, as it would have been, provided the sun had never existed; and that all of a sudden the sun was created; and that the earth began to revolve on its axis, and in its orbit, in reference to that luminary, just as it does at present. In that case, the amount of caloric driven into the earth during day by the repellent influence of the sun, would at first, and for a length of time, be greater, than the amount that would separate from it during night, just as is observed to take place, when the sun, in its course along the ecliptic, is returning from the winter towards the summer solstice; and even for several weeks after it has passed, and begun to retrograde from the summer solstice. Gradually, however, as the earth became heated, the difference between the amount absorbed during day, and given out during night, would become less, till they got, agreeably to the present state of things, completely equalized.

We arrive at a similar conclusion by examining the temperature of the earth in different latitudes. Thus, the annual variations of temperature become gradually less in digging down below the surface of the ground, till we reach the depth of about forty feet. At this depth, the temperature of the earth remains without any sensible alteration throughout the year; and coincides with the mean annual atmospheric temperature of the place, at the surface of the ground. Now, as the permanent temperature at the depth of forty feet decreases from the equator to the poles, it is obvious, that this unequal distribution of caloric in different latitudes, has resulted from the absorption of caloric, occasioned by the influence of the sun, continued for an indefinite duration of ages. Hence we are led to infer, that the amount of caloric intermixed with the ponderable materials composing the crust of the earth, is greater, even during night and winter, in every latitude, but more particularly so according as we approach the equator, than it would have been, if the equilibrium of the terrestrial caloric had never been subjected to the repellent influence of the sun.

Supposing the sun were to be annihilated, the distribution of the earth's caloric would, in that case, gradually return to what it would have been, provided the sun had never existed. The increased amount of caloric absorbed by, and intermixed with, the ponderable materials in the different latitudes, according to their proximity to the equator, would gradually separate from them; and a tide amongst the higher calorific strata would flow towards the polar regions, till the calorific equilibrium was everywhere restored. And this, if the sun were annihilated, as we are supposing, could only take place when the amount of caloric absorbed by the earth, and surrounding it, was equal in every latitude. Now, as the retrocession, or radiation of caloric from the earth in the absence of the sun during night, must be regulated both in direction and velocity, by the preponderance of pressure to which it is subjected; it follows, that the calorific tide during night, must in every quarter direct its course, so as most speedily to establish that calorific distribution in every latitude of the earth in which the calorific equilibrium, provided the sun had never existed, would consist. In consequence, however, of the rotatory rapidity with which the hemisphere of the globe, which is turned away from the sun during night, gets again presented to it; the retrocession of caloric from the side of the earth turned away from the sun, and the calorific tide from the equatorial towards the polar regions, can only proceed a very little way, when its course is reversed, by the repellent and compressing influence of the sun, upon the return of day.

SECTION XXVII.

OBJECTIONS TO THE PRECEDING THEORY OF THE SOLAR RADIATION OF HEAT ANTICIPATED AND ANSWERED.

It might be asked, by way of objection to the preceding theory, why the moon, which is likewise composed of ponderable and imponderable materials, does not give rise to calorific radiation alternately towards and from the earth, upon similar principles with the sun. To this objection we can only give a hypothetical answer. We previously stated, that the moon was about five and a half times as dense as the sun. On examining the substances on the earth's surfaces, we find that their densities diminish nearly in proportion as their specific heats increase. Now, judging from analogy, if the great density of the moon compared to that of the sun, be owing to its containing a much smaller proportion of caloric, relative to the amount of ponderable matter, there is an obvious reason why it should be incapable of causing the radiation of caloric towards the earth. The amount of caloric contained in the moon is probably in that case so small, as to be inadequate, not only to cause caloric to radiate towards the earth's surface, previously heated by solar radiation to a degree much beyond what its individual unassisted attraction for caloric can retain; but even incapable of obstructing, except possibly in a very slight degree, the retrocession of the additional heat, which the earth had absorbed during its previous diurnal exposure to the sun. In short, the earth's surface, even during night and winter, may be considered as always previously heated by solar influence, to a degree which the calorific repelling materials in the moon, vertically exerted, cannot maintain. But supposing the earth's surface had not previously been heated, and its temperature were as low as it would have been, provided the sun had never existed; the moon would probably, in that case, have produced an alternating calorific effect, similar to, but less powerful, than that caused at present by the sun. Caloric would then have radiated towards the surface of the earth presented to the moon; and again radiated from it, as that side, in the course of the globe's rotation on its axis, got turned away from the moon. I am inclined to think, that the influence of the moon in retarding the retrocession of caloric from the earth's surface during night, is too inconsiderable in all warm and temperate climates, to be detected amidst so many other disturbing causes. In very high latitudes, however, particularly during the latter half of winter, it is not impossible, but that some evidence of the moon's influence in that respect, might be obtained.

Again, it may be stated, by way of objection to our theory of the solar radiation of heat, that if the repulsive influence of caloric in the sun, or in any other celestial orb, occupies the same time in travelling to the earth by radiation, that light has been ascertained to do; such is only compatible with the supposition that the intervening space between the earth and all other celestial orbs, is occupied by caloric, light, or some other elastic medium, by means of the pulsations or undulations of which, the radiation of light and heat are propagated. In answer to this objection, it may be admitted as probable, that heat, or the repulsive influence of heat, travels from one celestial body to another, in the same manner, and with the same velocity as light, or rather perhaps with the same velocity as the repulsive influence of light. The common notions on this subject are formed from contemplating the propagation of waves on the surface of water, or deduced from the manner in which pulsations are conceived to be transmitted through the air, in the propagation of sound. We know that light travels by radiation through the atmosphere, with immensely greater rapidity than sound. But then, be it recollected, that sound only travels at the rate of 1142 feet, or rather less than a quarter of a mile in a second; whereas light has been ascertained to travel, not a hundred, or a thousand times, but nearly a million times faster, viz. at the rate of 195,000 miles in a second. If any ethereal fluid be diffused throughout the spaces intervening between different celestial bodies, it can only exist in that state of universal diffusion, in consequence of its parts, or particles, being mutually repellent. Any notions, however, that we can form of the rapidity by which a repellent influence could be propagated through such a medium, either in the form of pulsations, or undulations, falls immeasurably short of the rate at which light is propagated from one celestial body to another.

From the phenomena of the refraction, and reflection, of light and heat, in radiating through the atmosphere, from one body to another, on the earth's surface, we are led to believe that the repellent influence, and a slow receding movement of all luminiferous and calorific particles, are propagated to a distance, not only in straight lines, but also in refracted and reflected directions, with infinitely greater velocity than sound travels. And even were we to admit in this case, that the repellent influence is propagated from one stratum of particles to another, (which, from the susceptibility of its direction being altered by refraction, and reflection, seems probable,) and though we were also to admit, that the rate of propagation is infinitely more rapid than that with which sound travels; still, there is sufficient latitude for supposing, (and we have no means of determining the point,) that its rate of travelling in that manner, may fall infinitely short of 195,000 miles in a second.

If it be said, that it is impossible to conceive how a repellent influence can be propagated through a vacuum; or how such an influence should occupy any time whatever in travelling through it; we answer, that the notion of repulsion occupying time in traversing an elastic ethereal fluid, involves the same difficulty. The indispensable attribute of every thing material is that of having extension, or which amounts to the same thing, of occupying space to the exclusion of all other matter at the same instant of time; and we can form no distinct conception of any thing material which neither occupies space, nor has extension. Now, we cannot suppose that the ethereal fluid diffused throughout the celestial spaces, entirely fills them to the exclusion of all other matter. It follows, therefore, that if it exist at all, it must consist of parts or particles separated from each other by an intermediate vacuity. But if such parts or particles repel each other, which, as has been already stated, is the only principle upon which their universal diffusion throughout space could be accounted for; it follows, that if a repellent influence occupies any time whatever in being transmitted by pulsations through any distance, however great, of such particles, that a portion of time must elapse, however inappreciably small, in transmitting the repellent influence through the vacuity between one such particle and another. To reason satisfactorily, however, on such subjects, which are more or less connected with the idea of infinity, is beyond the limits of human faculties. To extend such observations, therefore, would only be to involve ourselves in a labyrinth of inexplicable difficulties, without the possibility of arriving at any certain conclusion.

Since our faculties are too circumscribed to enable us to reason satisfactorily on such subjects, we have no means of settling the question under consideration. Nevertheless, when the objections we previously urged against the supposed existence of a resisting medium occupying space are considered; it seems fully more probable, that the repellent influence of both heat and light is capable of traversing celestial vacuity at the rate of 195,000 miles in a second, without the aid of any material line of communication, in the same manner as attraction is supposed to do, than that it should proceed with such inconceivable velocity by propagating pulsations, or undulations, from one stratum of particles to another. Besides, upon the supposition that there is no ethereal fluid occupying the celestial spaces between different planetary bodies, it is more in accordance with our ordinary modes of reasoning to believe, that a repellent influence exerted by light concentrated around the sun, should be sooner felt on earth, than the repellent influence exerted by light concentrated around a star ten thousand times more distant. This idea, however, supposes, that the repellent influence of light occupies time in traversing celestial vacuity. And if this be the case, it is also probable, though we have no means of ascertaining the fact, that the attractive influence mutually exerted between ponderable materials, instead of being transmitted instantaneously to any distance, however great, occupies some corresponding appreciable length of time, in travelling from one planetary body to another.

SECTION XXVIII.

ON THE DIFFERENCE IN THE HEATING POWER OF THE SUN'S RAYS, IN DIFFERENT LATITUDES, AND AT DIFFERENT ALTITUDES ABOVE THE LEVEL OF THE SEA.

THE theory of the solar radiation of heat advanced in the preceding pages, affords an explanation of a meteorological fact, which has hitherto appeared so inexplicable to meteorologists, and so different from what might have been anticipated, that though it has been confirmed by the observations, and deductions, of Humboldt, Daniell, Saussure, and Captains Sabine, Parry, and Scoresby, its truth has never yet been fully admitted. The fact alluded to is, that the maximum diurnal heating influence of the sun's rays, is least in equatorial latitudes, and gradually increases towards the polar regions. In evidence of this being the case, we will here insert a portion of the tables and observations made by different persons on this point, extracted from Professor Daniell's Meteorological Essays. We will begin with the Professor's own judiciously directed observations, which, he tells us, "were made by means of a register thermometer of large range, having its bulb covered with black wool, and placed upon a south border of garden-mould, with a full exposure to the sun. The thermometer did not rest upon the earth, but was supported about an inch above it. The following Table presents us with the average intensity of the solar radiation for every month in the year, or the mean greatest height of the black thermometer above the surrounding medium, together with the utmost intensity observed in the same periods. The first column exhibits the month, the second the mean maximum temperature of the air, the third the average effect, and the fourth the maximum energy of the sun's light.

TABLE I.—SHOWING THE MEAN MAXIMUM TEMPERATURE OF THE AIR, WITH THE MEAN AND MAXIMUM POWER OF THE SUN, FOR EVERY MONTH OF THE YEAR.

	Mean Maximum of the Air.	Mean Maximum Force of Solar Radiation.	Maximum Force of Solar Radiation.
January, . .	39·6	4·4	12·
February, . .	42·4	10·1	36·
March, . .	50·1	16·	49·
April, . . .	57·7	28·1	47·
May, . . .	62·9	30·5	57·
June, . . .	69·4	39·9	65·
July, . . .	69·2	25·8	55·
August, . . .	70·1	33·1	59·
September, .	65·6	32·7	54·
October, . .	55·7	27·5	43·
November, .	47·5	6·7	24·
December, . .	43·2	5·4	12·

TABLE II.—SHOWING THE PROGRESS OF SOLAR RADIATION, FROM MORNING TO EVENING, DURING A PERFECTLY CALM AND CLOUDLESS DAY IN JUNE, 1822, THE DEW POINT BY THE HYGROMETER BEING STATIONARY AT 57°.

THERMOMETER.

	Time.	In Sun.	In Shade.	Difference.
A.M.	9	93	68	25
—	9½	103	69	34
—	10	111	70½	40½
—	10½	119	71	48
—	11	124	71½	52½
—	11½	125	72½	52½
—	12	129	73	56
P.M.	0½	132	74	58
—	1	141	74½	66½
—	1½	140	75	65
—	2	143	75½	67½
—	2½	138	76	62
—	3	138	76½	61½
—	3½	132	77	55
—	4	124	76	48
—	4½	123	77	46
—	5	112	76	36
—	5½	106	75	31
—	6	100	73	27
	Means, .	124¾	73½	51¼

TABLE III.—SHOWING THE PROGRESS OF SOLAR RADIATION, FROM MORNING TO EVENING, IN JUNE, UPON AN AVERAGE OF FIVE EXPERIMENTS.

Time.	Force of Sun's Rays.
9½ A.M.	32
10½	46
11½	55

Time.	Force of Sun's Rays.
12½	63
1½ P. M.	65
2½	63
3½	58
4½	49
5½	35
7½	29

The following are Tables and Observations made by Captains Sabine, Parry, and Scoresby, extracted from the same source, and accompanied with a portion of Professor Daniell's remarks.

TABLE V.—EXPERIMENTS UPON SOLAR RADIATION, AT SIERRA LEONE, BY CAPTAIN SABINE.

MARCH 4.

Time.	No. 1.	No. 2.	Difference.
A. M. 9	80	95	15
— 10	80·5	93	12·5
— 11	80	94	14
— 12	80·2	98·5	18·3
P. M. 1	80·8	96	15·2
— 2	81	97	16·
— 3	83	90·5	7·5
— 4	82·5	89·5	7·

"The first, and most striking result of these observations, is the very small comparative energy of the solar rays. All the means adopted to measure their effect concur in this conclusion. The utmost difference between a blackened thermometer in the sun, and another in the shade, was only 18·3 degrees."

"The next series of experiments, which were made at Bahia, on the coast of Brazil, come into more immediate comparison with my own, (Professor Daniell's,) and agree in the conclusion of the diminution of the force of radiation from a tropical sun. A mercurial register thermometer, having its bulb blackened and covered with black wool, was fully exposed to the sun on grass, and compared with a thermometer in the shade; the following Table exhibits the results."

TABLE VI.—EXPERIMENTS UPON SOLAR RADIATION, AT BAHIA, BY CAPTAIN SABINE.

	Sun.	Shade.	Difference.
July 24,	114	82	32
— 25,	123	82	41
— 26,	124	83	41
— 27,	123	83	40
— 28,	95	78	17
— 29,	115	78	37
— 30,	127	80	47

"Here the maximum effect was only 47°, with a nearly vertical sun; while the same influence, in our temperate climate in June, in a medium not much less heated, was 65°."

TABLE VII.—EXPERIMENTS UPON SOLAR RADIATION, AT JAMAICA, BY CAPTAIN SABINE.

	Sun.	Shade.	Difference.
August 25,	122	86	36
— 26,	123	87	36
— 27,	122	86	36
— 28,	122	86	36
— 29,	123	86·5	36·5
— 30,	123	86·5	36·5

In the above experiments "the thermometer, with black wool, was exposed to the sun on the vegetation by which Port Royal is surrounded. It is a tongue of sand, projecting a considerable distance into the sea, and overrun by the Tibullus Maximus, which was at the time in flower. The ball of the thermometer was in contact with the vegetation, and supported by it about ten inches off the ground."

"In looking over the interesting personal narrative of M. de Humboldt, I find ample confirmation of these observations. At Cumana he remarks, 'I have often endeavoured to measure the power of the sun, by two thermometers of mercury, perfectly equal, one of which remained exposed to the sun, while the other was placed in the shade. The difference resulting from the absorption of the rays in the ball of the instrument never exceeded 3° 7, (6° 6 Fahr.) Sometimes it did not rise higher even than one or two degrees.'—*Humboldt's Travels, by H. M. Williams*, Vol. II. p. 58."

TABLE XI.—EXPERIMENTS UPON SOLAR RADIATION, AT MELVILLE ISLAND, BY CAPTAIN PARRY, THE THERMOMETER IN THE SUN BEING PLACED AT A DISTANCE FROM THE SHIP, AND THE WEATHER VERY FINE AND CALM.

	Time.	Sun.	Shade.	Difference.
Date—*March* 25,	12	+ 30	— 25	55
—	P.M. 1	+ 17	— 22	39
—	2	+ 25	— 22	47
—	3	+ 21	— 22	43

"Here it is seen that the sun had power to raise a thermometer, which had not been prepared to receive its greatest impression, 55° in the month of March, at Melville Island, latitude 74° 30′; the maximum effect in the vicinity of London, latitude 51° 31′, in the same month, upon a thermometer covered with black wool, being only 49°.

"In Captain Scoresby's 'Account of the Arctic Regions,' there are also many remarks which powerfully confirm the same opinion. 'The force of the sun's rays,' he observes, 'is sometimes remarkable. Where they fall upon the snow-clad surface of the ice or land, they are, in a great measure, reflected, without producing any material elevation of temperature; but when they impinge on the black exterior of a ship, the pitch on one side occasionally becomes fluid, while ice is rapidly generated at the other; or, while a thermometer placed against the black paint work, on which the sun shines, indicates a temperature of 80° or 90°, or even more, on the opposite side of the ship a cold of 20° is sometimes found to prevail. This remarkable force of the sun's rays is accompanied with a corresponding intensity of light.'"—Vol. I. p. 378.

"In the account of Captain Scoresby's last voyage to Greenland, a direct experiment in latitude 80° 19′ confirms the same conclusion.

"'The sun broke through the clouds, and produced a powerful effect upon the temperature. At two A.M. the thermometer was 3° or 4° below Zero. At eight A.M. it was + 6°, and at ten A.M.

about + 14° in the shade. But the genial influence of the sun was still more striking. In a sheltered air, it produced the feeling of warmth; the black paint work of the side of the ship, on which the sun shone, was heated to a temperature of 90° or 100°, and the pitch about the bends became fluid. Thus, while on one side was uncommon warmth, on the opposite side was intense freezing.'—*Journal of a Voyage to the Northern Whale Fishery*, p. 34. The radiating force of the sun must, therefore, have been 80° in the month of April."

It appears also that the heating power of the sun's rays, is greater in elevated regions, than in low lying places. On this point Professor Daniell says, "A fourth set of Captain Sabine's experiments, in the mountains of Jamaica, present a comparison of the greatest interest. The observations were made on the 31st of October, at Mr. Chisholm's house, situated on the summit of the Port Royal ridge, 4,000 feet above the sea. The woolled thermometer was laid upon the grass plat about 100 yards from the house, and fairly exposed to the sun. In the forenoon, in intervals of the breeze, when the sky was clear, it rose above 130°; the thermometer in the shade, at the time, being 73°. The difference of 57° exhibits a much greater intensity of action than any that had been obtained at the level of the sea." And in another passage Professor Daniell says: "With respect to the greater energy of the solar rays upon the summit of a mountain, than upon a plain, I find that Monsieur de Saussure made some decisive experiments, which establish the same fact." From these, and other similar facts, Professor Daniell concludes, that the power of solar radiation increases from the equator to the poles, and from below upwards.

SECTION XXIX.

ON THE DIFFERENCE IN THE FORCE OF RADIATION FROM THE EARTH'S SURFACE, DURING NIGHT, IN DIFFERENT LATITUDES, AND AT DIFFERENT ALTITUDES ABOVE THE LEVEL OF THE SEA.

From a variety of other observations narrated and commented upon by Professor Daniell, a portion of which we will likewise here insert, it also appears, that the retrocession or radiation of heat from the earth's surface during night, as might have been anticipated, likewise increases in a corresponding degree from the equator to the poles. "The following table exhibits the mean effect of radiation for every month, deduced from the averages of three years, together with its greatest observed intensity in the same intervals. The first column shows the month, the second the mean temperature of the air, the third the mean effect, and the fourth the maximum force of radiation. The results were obtained by Professor Daniell, by exposing, upon short grass, a register thermometer to an open aspect of the sky, having its bulb covered with black wool."

TABLE XII.—SHOWING THE MEAN MINIMUM TEMPERATURE OF THE AIR, WITH THE MEAN AND MAXIMUM FORCE OF TERRESTRIAL RADIATION, FOR EVERY MONTH IN THE YEAR.

	Mean Minimum of the Air.	Mean Depression from Radiation.	Maximum Depression from Radiation.
January, . .	32·6	3·5	10
February, . .	33·7	4·7	10
March, . .	37·7	5·5	10
April, . . .	42·2	6·2	14
May, . . .	45·1	4·2	13
June, . . .	48·1	5·2	17
July, . . .	52·2	3·6	13
August, . . .	52·9	5·2	12
September, .	50·1	5·4	13
October, . .	42·1	4·8	11
November, .	38·3	3·6	10
December, . .	35·4	3·5	11

"The power of radiation, as exhibited in the table, has evidently a tendency to increase with the heat, although the effect is marked by too many disturbing causes to have enabled us to discover the law of its progression. The amount of effect denoted in the third column, is principally dependent upon the clearness of the atmosphere, and it affords no bad estimate of the comparative brightness of the different months. April appears to be the clearest month of the year, and the cloudy state of July, in the midst of summer, is very remarkable."

"At Bahia, Captain Sabine exposed upon grass to the aspect of the sky, an alcohol thermometer, registering the extreme cold, and having its bulb covered with black wool. The following is the comparison between its indications, and those of a register thermometer placed under shelter."

TABLE XIII.—EXPERIMENTS UPON TERRESTRIAL RADIATION, AT BAHIA.

	Temperature of Air.	Temperature of Radiation.	Difference.	Observations.
July 24,	68	63·5	4·5	Dew.
— 25,	68	63·5	4·5	do.
— 26,	72	62·5	9·5	do.
— 27,	70	61·	9·	do.
— 28,	64	60·5	3·5	
— 29,	67	59·5	7·5	
— 30,	65	64·	1·	

"At Jamaica, the radiating thermometer was placed in the manner before described, in contact with the vegetation, and supported by it about ten inches above the ground. The following are the results:—

TABLE XIV.—EXPERIMENTS UPON TERRESTRIAL RADIATION, AT JAMAICA.

	Temperature of Air.	Temperature of Radiation.	Difference.
October 25,	76	72	4
— 26,	76	69	7
— 27,	76	65	11
— 28,	76	66	10
— 29,	76·5	65	11·5
— 30,	76	65	11
November 3,	76	67	9

"On the mountains, at 4000 feet above the level of the sea, the thermometer, laid upon grass, afforded the following comparison:

TABLE XV.—EXPERIMENTS UPON TERRESTRIAL RADIATION UPON THE MOUNTAINS OF JAMAICA.

Date.	Time.	Temp. of Air.	Temp. of Radia.	Difference.	Observations.
Oct. 31,	P.M. 10	65	51	14	Clear and calm.
Nov. 1,	A.M. 5	63	45	18	do. do.
—	P.M. 11	64	51	13	Clear, and gentle breezes.
— 2,	A.M. 5	64	55	9	do. do.

"From all these experiments taken together, it would appear that the same cause which obstructs the passage of radiant heat in the atmosphere from the sun, opposes also its transmission from the earth into space. The force of radiation for the given temperature is less between the tropics than at the latitude of London; and it obviously increases as we ascend above the surface of the earth." Such is an abridged account of the information communicated on this subject by Professor Daniell, in his 'Essay upon the Radiation of Heat in the Atmosphere.' By collecting together the scattered evidence on the subject, and adding considerably to it himself, he has established the facts of the case beyond all controversy. In his explanation of them, however, upon the consideration of which we are next to enter, he is far from being so successful.

SECTION XXX.

REFUTATION OF PROFESSOR DANIELL'S EXPLANATION OF THE PHENOMENA QUOTED IN THE TWO PRECEDING SECTIONS.

In explanation of the phenomena recorded in the two preceding Sections, Professor Daniell says, "May not the phenomena be owing to the differences in the thicknesses of the strata through which the radiant matter has to pass? The retardation of its passage, at the equator, may be dependent upon the inflation of the atmosphere over that zone, both from the centrifugal force of the motion of rotation, and from the expansion occasioned by the never-failing heat: its acceleration at the poles, to the comparative thinness of the aerial stratum, dependent upon cold, and a state of rest. As we ascend in the atmosphere, we obviously diminish the height of the stratum above us, and therefore the effect may be referred to the same explanation.

"It is well known that a considerable portion of the light of the sun is always detained, and absorbed in its passage through the atmosphere; and it has been calculated, that a vertical ray, shot through the clearest air, would lose more than a fifth part of its intensity. This absorption, supposing the aerial covering of the earth to be everywhere equal, would be in proportion to the obliquity of the rays;

for, as their course receded from the perpendicular, they would have to encounter a greater thickness of the aerial fluid. But if the form of the atmosphere be that of a greatly-oblate spheroid, the thickness of the equatorial stratum may readily be conceived to counterbalance, or exceed the obliquity of the course by which the rays would penetrate to the flattened regions of the pole. Now, the inequality of the temperature of the earth, must evidently impress such a figure upon the elastic atmosphere; and supposing the pressure to be everywhere equal, and the heat to increase from the pole to the equator, from 0° to 80°, the equatorial axis would be to the polar as 6 to 5."

It is unnecessary to quote the remainder of Professor Daniell's explanation. He seems to be very far from being satisfied with it himself; for in concluding it, he says, (p. 229,) "These suggestions, however, are offered with much diffidence, as I am well aware that the subject stands greatly in need of further elucidation."

The preceding explanation of the phenomena will obviously appear erroneous from the mere statement of the fact, that the aerial expansion, at the estimated rate of $\frac{1}{480}$th part of its bulk for every degree of additional temperature, for 80 degrees, (which he takes as the mean difference between the equatorial and polar temperatures,) would only increase the perpendicular depth of the atmosphere at the equator, one-sixth part beyond what it is at the poles. Whereas, the difference of distance that the solar rays require to pass through the atmosphere, when they fall on the earth's surface at an angle of only 45 degrees, (and it increases rapidly as the angle of incidence becomes more acute,) is about one-half greater, than if they fell perpendicularly. And as the centrifugal force produced at the equator by the rotation of the earth on its axis, is only $\frac{1}{289}$th part of the force, or weight, by which all bodies tend to fall towards the earth, and only diminishes their weight to that extent; it is manifest, that the inflation, or greater depth of the atmosphere in the equatorial regions, arising from the earth's rotation, can afford little assistance in obviating the objection.

SECTION XXXI.

A NEW EXPLANATION OF THE DIFFERENCE IN THE FORCE OF CALORIFIC RADIATION TOWARDS, AND FROM THE EARTH'S SURFACE, IN DIFFERENT LATITUDES, AND AT DIFFERENT ALTITUDES ABOVE THE LEVEL OF THE SEA.

The facts quoted, as well as others, which, for the sake of brevity, have been omitted, though totally at variance with the projectile, and the vibratory theories of the solar radiation of heat, are in perfect harmony with that which we have advanced, and therefore so far confirm its truth. From Table I. it appears, that in temperate latitudes the maximum force of the solar rays, averaged for each month, increases, other things equal, according as they are exerted more vertically on the surface of the earth. This being a result perfectly in harmony with what might have been anticipated, requires no comment. From Tables II. and III. there appears at first sight to be a departure from this law, when observations are restricted to different hours of the same day. Upon inspecting Table II. however, it will be perceived, that this principally arises from the greater slowness with which the maximum diurnal temperature is attained in the shade, than in the sun. At six o'clock, P. M. the thermometer in the shade, exhibited as high a temperature as it did at mid-day; whereas, the thermometer in the sun, exhibited a temperature 29 degrees lower than it did at mid-day.

The stronger heating influence of the sun's rays, notwithstanding the greater obliquity with which they fall upon the earth's surface, at noon, during summer, in cold than in warm climates, is the remarkable fact that has puzzled meteorologists to account for; and of which our theory of the solar radiation of heat, affords a simple, and satisfactory explanation. When enumerating the forces that tend to prevent any farther absorption of the calorific atmosphere by the earth, it was stated, that the fourth one was, "Repulsion exerted by caloric, or other calorific repelling materials, contained within the earth's surface, towards the calorific atmosphere surrounding the earth." Now, as this force becomes stronger according as the amount of caloric previously absorbed is greater, or in other words, is stronger, (except for periodic variations,) according as the mean annual temperature of the place is warmer; it is obvious that this circumstance explains the whole mystery.

The heating power of the sun depends upon, and is estimated by, the amount of caloric, which by its repellent influence, it can compress towards the earth, and cause to be absorbed by bodies on its surface, in a given time. Now, as the particles of caloric are mutually repellent, it is evident, that the repulsion of all the caloric previously contained in the atmosphere, and the superficial strata of the earth, will resist the approach and the entrance of more. Hence it follows, that the warmer the climate, the stronger will be the counteractive resistance to the calorific repellent influence of the sun, in compressing the calorific atmosphere on the side of the earth presented to it. And as the moving velocity of the calorific atmosphere towards the earth's surface, under an equal degree of solar compression, must be slower according as the warmth of the climate, and the consequent counteractive resistance to the compressing influence, is greater; it is manifest, that the amount of caloric which reaches the earth, and is absorbed by bodies on its surface in a given time, will also diminish in proportion as the warmth of the climate increases.

It might be imagined, that in high latitudes, the very cold strata underneath the actual surface of the earth, would absorb caloric, upon the return of summer, as fast as it was supplied to the actual surface by radiation, and that no increase in the atmospheric temperature would then take place. This, however, is not the fact. There is no doubt that the rapidity with which caloric passes downwards, increases according as the difference in the temperature of the actual surface, and of the strata underneath, becomes greater. But however cold the inferior strata may be, caloric appears to be supplied to the actual surface of land and water, in all latitudes, by radiation, during day, much more rapidly than it passes downward to the inferior strata by conduction. And hence the reason why the temperature of the actual surface of the earth, and of the aerial strata immediately thereupon incumbent, rises during day.

Supposing the repellent force of the sun's vertical influence in causing the earth to absorb caloric, to be estimated at a given amount, and the sun were to shine vertically, without intermission, on the same portion of the earth's surface; it could be demonstrated, agreeably to the principle above stated, that as the earth became heated, the amount of caloric absorbed in a given time would proportionally diminish. And when the quantity absorbed at length became so great, that its repulsion counterbalanced the calorific repellent influence of the sun; the calorific equilibrium, so long as the sun and earth remained stationary, would be established, and the solar rays could have no farther heating power whatever.

A fact mentioned by Dr. Richardson is in accordance with the explanation now given. He states, that the heating influence of the solar rays in very high latitudes, was much stronger in the spring months when the ground was covered with snow, than in the summer months when the altitude of the sun was greatest. Dr. Richardson ascribes the greater heating influence of the sun in the spring months, to the then greater clearness of the air. There is no doubt that a difference in the clearness of the atmosphere, will materially affect the heating power of the solar rays. If, however, we consider the great difference in the temperature of the superficial strata of the earth in these high latitudes, in spring and in summer, it seems probable, that the effect ascribed by Dr. Richardson exclusively to the difference in the clearness of the atmosphere, ought to have been partly, if not principally, attributed to the smaller amount of caloric contained in the earth during the spring months, offering a less degree of repulsive resistance to the approach, and absorption of radiant caloric by the earth's surface.

To understand how the radiation of caloric from the earth's surface during night should be less, according to our theory, in warm than in cold latitudes, in the same proportion as the radiation of caloric towards, and its absorption by, the earth's surface during day, is diminished; it is necessary to recollect, that caloric existing in any direction; repels, and thereby counteracts and retards, with a force increasing with its amount, the approach of caloric radiating from any superiorly heated body, or surface. And it must also be recollected, that the force of radiation from any heated body or space, is proportional to the excess of caloric contained in that body or space, beyond what the calorific equilibrium, and consequent equality of temperature, and cessation of all radiation, requires.

In warm latitudes, in consequence of the diminution in the heating power of the sun's rays, which we have already accounted for, the superficial strata of the earth acquire, during day, a less excess of temperature beyond that of the incumbent atmosphere, than the superficial strata in colder latitudes do during each day in the summer half of the year. Now, the force of radiation from the earth's surface during night, other things equal, is proportional to the excess in the temperature of the earth, beyond that of the incumbent atmosphere; or in other words, is proportional to the amount of caloric that requires to pass from the earth to the atmosphere, in order to the restoration of the calorific equilibrium. Hence it is obvious, that the amount of caloric which radiates from any portion of the earth's surface during the nights throughout the year, (except for slight modifying circumstances which need not be here adverted to,) must be proportional to the amount that radiates towards, and is absorbed by that portion during the days throughout the year. And as the amount absorbed during a summer day by the superficial strata of the earth in cold latitudes, is greater, for reasons already mentioned, than the amount absorbed during day in intertropical climates; it is also obvious, that the force of radiation during night, from the earth's surface, in cold latitudes, must likewise be greater. And as caloric, wherever distributed, repels caloric with a force increasing directly with its quantity, and inversely with the square of the distance at which it acts; it need hardly be remarked, that owing to the nearly equal temperature which exists throughout the year, for no less a space than 30 degrees on each side of the equator, the temperature of the atmosphere, in warm latitudes, is but little reduced during night, by the withdrawal of caloric, by means of radiating calorific currents towards colder latitudes.

The greater heating influence of the sun's rays, at the height of 4000 feet, on the Port Royal Mountains in Jamaica, and also in other elevated regions, than what was observed near the level of the sea in the same latitude, admits of an explanation analogous to that which we have already given, of the greater heating power of the sun's rays in cold, than in warm climates. At the height of 4000 feet, the mean temperature of the superficial strata of the earth, ought to be reduced about 13 degrees below that of land near the level of the sea, on account of mere difference of elevation. And if we consider the effect of the excess of rain which falls in all such elevated regions, (and the falling of rain on the Port Royal Mountains, even during the dry season, is an every day occurrence,) combined with the evaporative influence of the wind in reducing the temperature of moistened surfaces; it is probable, that about 3 degrees of additional reduction of temperature should be allowed, making in all a difference of 16 degrees between the mean temperature of the superficial strata of the earth, at the elevation of 4000 feet, and at the level of the sea, in the same latitude. Now, the sun's influence in causing the radiation of caloric towards, and its absorption by the earth's surface, may be considered equal for the same latitude, whether the surface of the land at the place of observation be elevated, or low-lying. But as the amount of caloric contained in the superficial strata of the earth is much greater in the low-lying, than in the elevated region; the calorific repulsion, and consequent counteractive resistance to the approach and absorption of more caloric by the earth's surface, must also be proportionally stronger in the low-lying situation. Hence the chief reason of the greater heating power of the sun's rays, in the one place than the other.

In like manner, if a larger amount of radiant caloric be absorbed by the earth during day in the elevated than in the low-lying locality; the superficial strata of the earth in the elevated region, will acquire during day, a greater excess of temperature beyond that of the immediately incumbent atmosphere, than the superficial strata in the low-lying locality will do. Now, as the force of radiation from any portion of the earth's surface during night, other things equal, is proportional to the amount of caloric that requires to separate from the earth to the incumbent atmosphere, in order to restore the calorific equilibrium; it is obvious that it must be greatest in the elevated region.

It is also probable, that the greater force of calorific radiation towards, and from the earth's surface, in elevated regions, may be partly owing to the greater rarefaction of the atmosphere, and the smaller amount of it through which the radiant stream has to pass. Though the power of bodies in conducting caloric increases nearly in proportion to their density, the facility with which caloric radiates through them is thereby diminished. Thus the proportion of radiant caloric absorbed by the aerial particles in passing through a given space of dense atmosphere, is greater than the proportion absorbed in passing through a similar space of rarefied atmosphere. This circumstance, by co-operating with the cause previously assigned for the radiating force of caloric towards, and from the earth's surface, in the same latitude, being greater in an elevated than in a low-lying locality, must therefore tend to increase the effect. Such is the manner in which, agreeably to our theory of the solar radiation of heat, the singular and otherwise inexplicable peculiarities, observed in the force of calorific radiation towards, and from the earth's surface, in different latitudes, and at different elevations above the level of the sea, ought to be accounted for.

The greater aptitude of the earth to receive, or part with caloric by radiation, according as its superficial strata have been previously much reduced, or much raised in temperature, above the annual mean for the latitude, affords an explanation of various phenomena which are of great importance to mankind. Thus, the rapid transition from winter to summer, and from summer to winter, wherever the annual range of temperature is great, such as in high latitudes, and in all inland countries in the temperate zones; and likewise the remarkable rapidity with which vegetation, in all such climates, is promoted upon the return of summer, and again checked upon the approach of winter, are as much owing to this cause, as to the increased and diminished length of the days. Were it not for this providential arrangement, a large proportion of the present thickly peopled surface of the globe, would have been uninhabitable. Within the torrid zone, vegetation would have been withered and burnt up; and the solar heat would have been too powerful for the human constitution to endure. On the other hand, beyond the 50th parallel of latitude, the summer heat would have been insufficient to nourish, and ripen the fruits, and vegetable productions of the earth, upon which man and other animals depend for sustenance. In the effects produced, we witness a wonderful instance of the simplicity in the means, by which Providence has accomplished the most useful ends. And it deserves to be remarked, that in this, as well as in every other physical arrangement, Nature employs no other agency, but the permanently-inherent attractive or repulsive properties of matter.

The facts quoted from Daniell's Essays, which we have now endeavoured to explain, are strongly corroborative of the theory we previously advanced, in order to account for centrifugal velocity in planetary motion. If the maximum diurnal heating power of the sun at midsummer, or in very high latitudes, a month or two before midsummer, be greater in temperate than in intertropical latitudes; and greater in the polar regions, than it is in temperate climates; it is evident, that the heating power of the sun does not result from its projecting calorific particles in straight lines, in every direction, with the velocity of 195,000 miles in a second; nor in any vibratory motion which it communicates to terrestrial matter. If the heating power of the sun resulted from either of these causes, it inevitably follows, that it should be strongest in those latitudes where its influence was exerted most vertically, in the same manner as it becomes stronger, at any given place, about noon, than at any other period of the day. But the circumstance of such not being true, as has been satisfactorily demonstrated by the observations previously quoted, and which were made and related, not to confirm a favourite theory, but in opposition to that which is universally received, leads us to the unavoidable conclusion, that the heating influence of the sun is not solely dependent upon the perpendicularity with which his rays fall on the earth's surface; but that it is modified, and counteracted, by causes exclusively terrestrial. Besides, as the heating influence of the sun appears to be more restrained, and counteracted, according as the warmth of the climate is greater; we are led to the conclusion, that the sun repels caloric concentrated by attraction around the earth, and thereby causes it to be slowly absorbed by the materials composing its surface; and that this calorific repellent influence of the sun, and the amount of caloric absorbed by any portion of the earth's surface subjected thereto, is counteracted, and diminished, by every increase in the amount of caloric which that surface has previously absorbed.

Now, if it be admitted that the sun repels caloric contained in and concentrated around the superficial strata of the earth, as the facts we have quoted incontrovertibly demonstrate; it follows, that the notion at present universally received relative to the cause of planetary motion, viz. that it is dependent upon attraction without the aid of any repellent force, must be erroneous. And hence we are led to the final conclusion, that planetary motion, agreeably to the theory we have advanced, is the result of the conjoint influence of the inherent attractive and repulsive properties, mutually exerted by the different ponderable and imponderable materials of which planetary bodies are severally composed.

SECTION XXXII.

EXPLANATION OF THE REASON WHY RADIANT CALORIC IMPARTS LITTLE WARMTH TO THE ATMOSPHERE, IN RADIATING THROUGH IT.

The fact of radiant caloric, whether caused by solar influence, or by that of a hot body, heating an opaque substance at a distance, without raising, in an equal degree, or for some time at first, even perceptibly, the temperature of the atmosphere through which it passes, is usually, though erroneously, explained upon the projectile principle, by supposing, that calorific particles radiate with such inconceivable velocity, as not to have time to communicate warmth to the air in passing through it. If it be admitted, that the view of the radiation of heat which we have advanced is correct; it is manifest, that the fact above described, is owing, not to the velocity with which radiant calorific particles are projected, but to the extreme mobility of caloric distributed either in a vacuum, or amongst gaseous substances. Increase of temperature, whether applied to body or space, consists in an augmentation of the amount of caloric in that body or space. And it is owing to the above noticed extreme liability of particles of caloric to motion, when subjected to the slightest preponderance of calorific repulsion, and to their consequent tendency, whether in motion or at rest, to maintain their previous equal distances from each other, that no material accumulation in the atmospheric medium takes place, so long as the general calorific stream, in receding from the heated body, meets with no interruption from reacting or obstructing surfaces. So soon, however, as the radiating stream is interrupted by a solid or liquid substance, the portion of it which is reflected, exerts an instantaneous influence in repelling, and opposing the progress of the stream. And thus, as it were, by hemming in, and thereby partially preventing the escape of radiating heat, accumulation of caloric, and increase of temperature, between the radiating and reflecting surfaces is promoted; and this effect takes place more rapidly, according as the reflecting surface is more directly opposed to the radiating; and also according to the power of the reflector. The portion of the radiating stream which is absorbed, increases the temperature of the body that absorbs it. And according as this intercepting body becomes heated, the excess of caloric therein contained, exerts a proportionally increasing repulsive force upon surrounding caloric; and in fact becomes itself an opposing radiating surface. This increasing repulsive force, by operating as an auxiliary to the above-mentioned instantaneous influence of reflection, diminishes the velocity of the radiating stream, and thereby accelerates the accumulation of radiant caloric, and the increase of atmospheric temperature between the radiating and intercepting surfaces.

SECTION XXXIII.

SUMMARY OF THE MORE IMPORTANT INFORMATION CONNECTED WITH RADIATION, COMMUNICATED BY DR. WELLS, IN HIS ESSAY ON DEW.

Before concluding the subject of calorific radiation, we may notice several circumstances connected therewith, which affect the atmospheric temperature, and that of the earth's surface, during the alternate absorption and retrocession of radiant caloric, during day and night.

When watery vapours exist in the atmosphere in the form of visible mist or clouds, they obstruct a greater or less proportion of the radiating calorific stream, according to their density and thickness. But though a part of the radiating stream, in its progress towards the earth, may be absorbed in its passage through a cloud, the whole of the free, or intermediate portion of caloric beneath the cloud, will continue to radiate towards the earth, just as if there had been no cloud, or as if the whole stream had passed through it. Agreeably, however, to the principle of velocities being proportioned to the forces which produce them; the velocity of the radiating stream, and consequently its influence in heating bodies, and obstructing the cooling of heated bodies, at the earth's surface, will be diminished, in proportion to the quantity of caloric intercepted by the cloud.

During sunshine, when the temperature of the earth's surface is rising, caloric, instead of penetrating farther into the globe with the rapidity of radiation, imparts only a portion of its redundant heat to the subjacent strata, with the slow progress of conduction. The portion of the radiating stream which the earth cannot absorb with sufficient celerity, and the accumulation of caloric at the earth's surface, which thence arises, distributes itself so as to communicate increase of temperature to the atmosphere in a variety of ways. It is partly reflected by the earth's surface, at an angle corresponding to that of incidence; it is partly carried into the atmosphere by evaporation, and by conduction; and partly carried up by the ascension of successive atmospheric strata as they become heated, and consequently specifically lighter, by a temporary contiguity with the warm surface of the earth. Besides, as the ground acquires heat, the increasing repulsion of the caloric accumulating on, and near its surface, operates with a correspondingly augmenting force in counteracting the velocity of the radiating current, in its progress towards the earth; and this effect, agreeably to the law of distance, becomes stronger the nearer the heated ground is approached. Hence the reason of the rise in the atmospheric temperature being accelerated during sunshine, as the surface of the earth, during day and summer, becomes heated.

As clouds and visible vapours obstruct and absorb, according to their density, a greater or less portion of the calorific stream, caused by solar influence in its progress through the atmosphere, and thereby partially prevent its warmth from reaching the subjacent earth: so, in like manner, do they intercept and retard its retrocession, and thereby assist in retaining the caloric accumulated in the superficial strata of the earth during day, and summer, by diminishing the radiation of heat from its surface, during night, and winter. Cloudy weather thus prevents the temperature of the earth's surface, and that of contiguous atmospheric strata, from rising during day and summer, and from sinking during night and winter, so much as it would otherwise do. Hence one reason why a cloudy wet summer is invariably a cold one, and produces a late harvest; and why a cloudy winter is usually a mild one; and *vice versa*. Hence also one of a combination of causes, why in islands and seacoast countries, such as that which we inhabit, where cloudy and foggy weather are more prevalent than in inland dry countries, on the same parallel of latitude, such as the interior parts of Russia, we are unacquainted with the extremes of heat and cold to which they are subjected.

That heat radiated, when the sky was clear, towards the side of the earth presented to the sun, could not escape the observation even of the most ignorant; but that it again radiated, or in other words, that it again escaped in the form of radiation from the side of the earth turned away from the sun, is but a recent discovery. This latter fact, though previously surmised, was first established by observations made by Dr. Wells, with the view of explaining the nature and cause of dew. That philosopher compared the temperature of the earth's surface, as indicated by a thermometer laid upon it, with that of the incumbent atmosphere, at various heights, chiefly, however, about four feet above the ground, during clear and cloudy nights: also during the temporary supervention of clouds, and subsequently to their passing away in the same night. During still nights, and in the absence of clouds, he observed that the atmospheric temperature on the surface of the ground sunk uniformly, sometimes as much as from 10 to 15 degrees, below that of the air four feet above it; and the more so according as that surface was better fitted for radiating caloric; and also, according as the subjacent strata, by the inferiority of its conducting power, more tardily supplied caloric, to replace that which had radiated. The amount of dew precipitated on different surfaces, appeared also, in equally favourable circumstances, to be proportional to the excess of coldness produced on those surfaces, beyond that of the incumbent atmosphere. During cloudy nights, or during the temporary supervention of clouds, this difference of temperature between the surface of the ground and that of the air four feet above it, if it appeared at all, was less; and the deposition of dew was also proportionally diminished; and subsequently to the passing away of clouds, the difference of temperature, and the deposition of dew, soon became greater.

"If the night became cloudy," says Dr. Wells, "after having been clear, though there might be no change with respect to calmness, a considerable alteration in the temperature of the grass always ensued, and this sometimes very suddenly. Upon one such night, the grass, after having been 12° colder than the air, became only 2° colder than it, the temperature of the air being the same at both observations. On a second night, grass became 9° warmer in the space of an hour and a half. On a third night, in less than 45 minutes, for the whole change occurred while I was absent 45 minutes, the temperature of the grass rose 15°, while that of the neighbouring air increased 3½°. During a fourth night, the temperature of the grass at half-past 9 o'clock was 32°. In 20 minutes afterwards it was found to be 39°, the sky having in the meantime become cloudy. At the end of 20 minutes more, the sky being clear, the temperature of the grass was again 32°." These facts explain the reason why we feel colder in the open air during night when the sky is clear, than when it is o'ercast with clouds, though the temperature in both cases, as indicated by a thermometer, be the same. The radiation of heat from the surface of our clothing, just as from grass, is less obstructed in the former circumstances than in the latter.

Awnings, even though of a very thin texture, such as cambric muslin, (and their efficacy is greater when somewhat separated from the body sheltered, than when in actual contact therewith,) or indeed whatever diminishes the view of the sky as seen from the body exposed, have a similar effect with clouds, in equalizing the temperature at, and near its surface, and accordingly in diminishing the degree of coldness that would otherwise be produced by the radiation of heat from the surface of bodies, and in lessening the deposition of dew thereon. "I bent," says Dr. Wells, "a sheet of pasteboard into the shape of a house-roof, making the angle of flexure 90 degrees, and leaving both ends open. This was placed one evening, with its ridge uppermost, upon the same grass-plat, in the direction of the wind, as well as this could be ascertained. I then laid 10 grains of wool on the middle of that part of the grass, which was sheltered by the roof, and the same quantity on another part of the grass-plat fully exposed to the sky. In the morning, the sheltered wool was found to have increased in weight only two grains; but that which had been exposed to the sky, sixteen grains."

From the preceding experiments, we see the advantage of a roof as a protection, during clear calm nights, from the cold we would otherwise experience, by the radiation of heat from our bodies. During such nights, an umbrella might almost have as much influence in affording shelter from the effects of cold, as it has during day, in affording shelter from the heat of the sun. Upon analogous principles, Dr. Wells considers garden walls favourable to temperature, not only by sheltering trees and vegetables near them from cold winds, as well as by slowly giving out the heat which they had acquired through the day, but also, by diminishing the exposure to the sky, and thereby lessening the loss of heat which they would otherwise sustain during night from radiation. Dr. Wells also conceives that a covering of snow in high latitudes, and in dry inland countries, is principally useful in protecting plants, not as is usually supposed from the coldness of the atmosphere, but from the extreme cold arising from radiation, to which the surface of the ground would be otherwise subjected.

From an infinity of facts, ascertained by laborious and careful observations, and varied in every possible shape to avoid inaccuracy, Dr. Wells demonstrated, that dew results from the precipitation of moisture from the atmospheric stratum nearest the earth's surface, in consequence of its temperature being lowered, and its capacity for moisture diminished, by contact with the surface of the ground, which, in order to the effect, must be previously cooled by radiation. Hence, other things equal, the more susceptible a surface is of becoming colder than the incumbent atmosphere by radiation, and of communicating its coldness to that portion with which it is in immediate contact, the more apt it is to be bedewed. Dr. Wells also proved by experiments, that the reduction of temperature which the radiating surface exhibited, beyond that of the air four feet above it, did not wholly depend upon the goodness of the surface for radiating caloric; but was partly owing to the slowness with which heat passed upwards from underneath, by conduction, to the radiating surface, to supply the place of that which had radiated. According to the experiments of Saussure, the capacity of the atmosphere for containing moisture diminishes in geometric progression as its temperature decreases. Hence, if the atmosphere be replete with moisture, the slightest reduction of its temperature must be accompanied with a precipitation of humidity. And even though the atmosphere a few feet above the ground be considerably under the point of repletion, such a reduction of temperature, as that to which its lowest stratum is subjected, by contact with the cold radiating surface of the earth during serene starry nights, may be expected to reduce its capacity for humidity so much, as to cause some degree of deposition.

That the reduction of temperature observed on the earth's surface, beyond that of the atmosphere a few feet above it, was owing to the radiation of its heat, Dr. Wells demonstrated, by the fact of its being greater, other things being equal, in proportion to the power of the surface in radiating caloric. And that the phenomenon of dew depended upon such reductions of temperature, he also established by the fact of the quantity of dew simultaneously precipitated upon different radiating surfaces, being proportionally more copious, as the reduction of temperature, indicated by a thermometer laid upon them, was greater. Thus, polished metallic plates, which are the worst radiators of caloric, had less effect in reducing the temperature of the air in immediate contact with them, relative to that of the atmosphere four feet above, than any other substances, and least dew, if any at all, was deposited upon them. A gravel walk had more influence in reducing the temperature of the air in immediate contact, and in acquiring dew, than metallic plates; and shavings of wood had more effect than a smooth board. Filamentous and downy substances had generally most influence. Thus, grass-plat had much more effect than a gravel walk; and swandown, adhering to the skin of the animal, had somewhat more influence than grass-plat.

The effect of wind in diminishing the difference between the temperature of the earth's surface, and that of the atmosphere a few feet above it, and thereby, in preventing or lessening the precipitation of dew, Dr. Wells satisfactorily explains, by ascribing it to the constant agitation, and mixture of the air nearest the ground, with the less cooled superior strata. "Bodies," says Dr. Wells, "exposed in a clear night to the sky, must radiate as much heat to it, during the prevalence of wind, as they would do if the air were altogether still. But in the former case, little or no cold will be observed upon them above that of the atmosphere, as the frequent application of warm air must quickly return a heat equal, or nearly so, to that which they had lost by radiation."

Dr. Wells also explains the fact of a thermometer suspended in the air a few feet from the ground, exhibiting little reduction of temperature from radiation, in comparison with what it shows, if laid on the middle, or rather nearer the lee side of a board, of considerable dimensions, placed horizontally at a similar height from the ground. The suspended thermometer is continually exposed to the application of fresh parcels of warmer air, in consequence of the downward motion produced by the superior gravity of such portions as have been cooled by contact with the bulb; whereas, the horizontal board interrupts this downward movement of the portion of air cooled by contact with its surface. Similar explanations are also given why the quantity of dew precipitated upon lofty trees is smaller than upon grass, herbs, bushes, and shrubs; and likewise why the amount of dew deposited on declivities, is less than upon level plains.

Dr. Wells also shows, that the formation of dew, like every other precipitation of water from the atmosphere, produces heat; and is consequently a means of lessening the reduction of temperature on the radiating surface. During eight hours of a particularly dewy night, he calculated that the mean quantity of cold which the deposition of dew prevented from appearing on the surface of the ground, was about 4½ degrees. But as the formation of dew was not equable throughout the night, he estimated the diminution of cold thereby produced, when it was most copiously precipitated, to be about 6 degrees. The condensation of invisible vapour, whether into dew, mist, clouds, or water, is said to be accompanied with the evolution of caloric, to no less an extent than 940 degrees of temperature, being the same quantity that water absorbs in the opposite transition from the liquid to the gaseous state. Hence may be deduced one cause of the great effect of northerly and easterly winds in this island, particularly during the latter half of Spring, in the production of cold on the earth's surface, and of the comparative smallness in the quantity of dew which they deposit. During that season of the year, those winds blow from a cold towards a warmer climate; and as their capacity for humidity increases in geometric progression as they become heated in their course, they are usually more under-saturated with moisture than any others; and consequently must undergo a greater reduction of temperature before they begin to deposit dew. During day, their dryness produces cold by promoting evaporation from all moist surfaces; and hence their refrigerating influence, relative to their thermometric temperature, upon the human body. And during night, they deposit little or no dew, to mitigate the severity of the cold, on the surface of the ground, resulting from radiation.

Dr. Wells also happily explains the reason why the cold during serene nights, is most hurtful to vegetables in hollow places; and likewise, the effect of artificial depressions in the earth, such as are made in the East Indies, for the purpose of increasing the cold, and producing ice, when the temperature of the air a few feet above those depressions, may be 15 degrees, or more, above the freezing point. At night, it is hardly ever so calm but the air is subjected to some degree of progressive motion; and the undermost stratum is therefore liable to a corresponding degree of agitation, and mixture with those immediately above. In hollows, the atmosphere, being less exposed to currents, is stiller than in other places. Besides, the coldness, and consequent increased specific gravity, communicated to its undermost portion by contact with the radiating surface of the ground, co-operates with the shelter thus afforded, and renders it better able to retain its low situation. Hence, when the undermost stratum of air is cooled, and has parted with a portion of its moisture, the coldness produced on the surface of the ground by radiation, is subsequently less mitigated in such places by renewed applications of warmer parcels of air, and by the heat which would be evolved during their successive depositions of dew.

On hills and eminences of moderate height, except it be table land, the opposite circumstances, according to Dr. Wells, take place. Such elevations are more exposed to aerial currents; and owing to their convex form, any increase in specific gravity, arising from coldness communicated to the portion of the atmosphere nearest the ground, and which in hollows favours stillness, there produces agitation, by creating a tendency to descend to a lower level. Hence the cold resulting from radiation, and the amount of dew, or hoar-frost, (which is dew frozen,) deposited on the surface of hills during calm cloudless nights, is less than on open plains.

Dr. Wells also successfully explains the appearance of moisture during night, on the inside of panes of glass, and the influence of an inside shutter in increasing that effect. "I observed one morning in winter," says Dr. Wells, "that the inside of panes of glass, in the windows of my bed-chamber, were all of them moist, but that those of them which had been covered by a shutter during the night, were much more so, than those which had been uncovered. Supposing that this diversity of appearance depended upon a difference of temperature, I applied the naked bulbs of two delicate thermometers to a covered and uncovered pane; on which I found that the former was 3° colder than the latter. The air of the chamber, though no fire was kept in it, was at this time 11½° warmer than that without." Dr. Wells with propriety ascribes the appearance of the moisture on the insides of the panes, to the communication of the external coldness, through the glass, to the air within the apartment in immediate contact therewith, causing a precipitation of moisture in a manner perfectly analogous to that in which dew is deposited on any chilled surface. And the greater reduction of temperature, and increased deposition of moisture upon the panes sheltered from the interior of the apartment by the shutter, than upon those that were not so protected, he also with reason ascribes to the influence of the shutter in shielding the glass which it covered, from the heat radiated to the windows by the walls, and furniture of the room.

The formation of ice, in frosty weather, on the inside of panes of glass, and the influence of an inside shutter in increasing the effect, may be explained in the same manner as the deposition of moisture, in similar circumstances, is accounted for by Dr. Wells. The precipitation of moisture, on the panes of glass, in both cases, depends upon the same cause; and the circumstance of its being frozen, or not frozen, is determined by the lowness of temperature to which, either after, or at the time of precipitation, it is subjected.

We may here explain certain analogous phenomena to those above stated, that presented themselves at Glasgow, on the morning of the 2d of January, 1837, and which were not generally understood. Early in the morning of the 1st of January, my self-registering thermometer indicated that the temperature had been as low, during th night, as 15° of Fahrenheit, and out of town it had been as low as 10°. At 10 o'clock, A.M. the temperature at my house in town was 21° Fahrenheit, and it continued nearly as low till the evening. The wind was north-east, but it had almost subsided into a perfect calm. About six o'clock, P.M. the wind shifted to the west, and by 11 o'clock, P.M. the temperature had risen to 34° Fahrenheit. Of course, this westerly wind, which blew very gently, must have been very nearly saturated with moisture, in consequence of coming from the Atlantic, and from having its temperature reduced in passing over the cold frozen surface of the land. On the morning of the 2d January, the temperature of the air being 35°, the external walls of the houses were white with hoar-frost; and during the day, the inside walls of apartments in which there were no fires, were generally damp, and in many cases, absolutely wet with moisture. The hoar-frost on the outside walls of the houses, and the moisture which made its appearance on the walls within the apartments in which there were no fires, were erroneously ascribed to dampness coming out of the walls upon the cessation of the frost. The true explanation of the phenomena is as follows:—After the wind shifted to the west, and the atmospheric temperature rose above the freezing point, the walls of the houses, both externally and internally, having been chilled during the previous severe frost, were colder than the air. Of course, the stratum of air which came into immediate contact with the chilled walls, had its temperature thereby so much reduced as to become over-saturated, and consequently it precipitated a portion of its moisture upon the walls, just in the same manner as dew, during serene nights, is precipitated from the atmospheric strata, upon coming into contact with the then colder surface of the earth. And also upon the same principle, as moisture is deposited upon hygrometric instruments, when their temperature is artificially reduced in order to determine the dew point. The circumstance of the moisture assuming the appearance of hoar-frost on the external walls of the houses, was owing to the greater degree of cold to which it was there exposed.

SECTION XXXIV.

EXPLANATIONS OF PHENOMENA NOTICED BY DR. WELLS, WHICH HE HAS EITHER EXPLAINED ERRONEOUSLY, OR LEFT TOTALLY UNEXPLAINED.

Explanation of the Influence of Clouds and Awnings, in Obstructing the Radiation of Heat from the Earth's Surface.—The explanations given by Dr. Wells, of the manner in which clouds and awnings, and whatever diminishes the view of the sky, prevent, or lessen the coldness arising from radiation, appearing at night on the earth's surface, are, in my opinion, erroneous. They are founded upon Prevost's theory of the radiation of heat, the absurdity and mechanical impossibility of which we have already exposed in Section XXII. Indeed, Dr. Wells' adoption of Prevost's notions upon this subject, and the frequent allusion to them, in order to explain phenomena which counteract the appearance of cold on radiating surfaces, and the consequent formation of dew, give rise to an error that pervades his whole theory. The following extracts, on the effect of clouds in preventing the appearance of cold on the earth's surface, will illustrate this point.

" No direct experiments," says Dr. Wells, " can be made to ascertain the manner in which clouds prevent, or occasion to be small, the appearance of a cold at night, upon the surface of the earth, greater than that of the atmosphere; but it may, I think, be firmly concluded, from what has been said in the preceding article, that they produce this effect, almost entirely, by radiating heat to the earth, in return for that which they intercept in its progress from the earth towards the heavens." And again, in a subsequent passage on the same subject, he says: " Dense clouds near the earth, must possess the same heat as the lower atmosphere, and will therefore send to the earth, as much, or nearly as much heat as they receive from it by radiation. But similarly dense clouds, if very high, though they equally intercept the communication of the earth with the sky, yet being, from their elevated situation, colder than the earth, will radiate to it less heat than they receive from it, and may, consequently, admit of bodies on its surface becoming several degrees colder than the air. In the first part of this Essay, an example was given of a body on the ground becoming at night 5° colder than the air, though the whole sky was thickly covered with light clouds."

Such is a specimen of the errors into which Dr. Wells falls, by his adoption of Prevost's theory of radiation. Instead, however, of here attempting to show the absurdity of the above reasoning, which would be merely a repetition of our former arguments, we will refer the reader to the refutation which we have already given of Prevost's theory, and to the development of our views regarding the nature of radiation, which follows that refutation. We may, however, so far recapitulate, as to remind the reader, that particles of caloric are at all times subjected to a greater or less degree of calorific repulsion on every side, and that their movements, like those of all other bodies, must ever obey the preponderance of pressure. When the pressure on every side is equal, they must remain stationary, as, in this case, no reason can be assigned why they should move in one direction, more than in another. When the pressure on different sides is unequal, motion must result; but whether by radiation or conduction, can only be in one direction, viz. from where the preponderance is greatest, to where the resistance is least.

Clouds, in the situation of screens, intercept and counteract radiation, upon precisely similar principles with all other intercepting substances. They may be regarded among the best absorbers of radiant caloric, and of course are among its worst reflectors, and in proportion to their thickness, are among its worst interceptors. Indeed, I am not aware of any experiments ever made to ascertain whether or not clouds reflect heat. But as it is obvious that they reflect light, it is probable, that like other opaque bodies, they also in some degree reflect heat, and thereby assist in counteracting the retrocession of caloric from the earth during night.

The other means, besides reflection, whereby screens intercept and counteract radiation, results from the increasing repulsion which the caloric absorbed, and concentrated by the substance of the screen, presents, as its temperature rises. This means of intercepting radiation differs from reflection in this, that the latter acts with its full power, though the intercepting substance be ever so cold; whereas, the former only begins to operate when the intercepting substance begins to be heated, and unlike reflection, goes on with augmenting effect as its temperature increases. In reference to this latter means of intercepting radiation, there is a peculiarity in regard to clouds which may be admitted to be so far hypothetical, as it is merely inferred, and has never been proven by experiment. It is, that the temperature of clouds must be usually, if not constantly, higher than that of the pellucid atmosphere, at a similar elevation; and accordingly, their existence or temporary supervention in the atmosphere, must, from this circumstance, counteract radiation as instantaneously and certainly; and except for difference in density and volume, and perhaps other slight modifying causes not worth noticing, nearly as uniformly as reflecting surfaces. The reasons which induce me to think that this must be the case are the following:—

1*st*. Moisture, in its transition from the pellucid state to that of clouds or fog, evolves heat; and it does not matter whether the transition be owing to a gradual reduction in the temperature of the atmosphere, when replete with moisture, or, agreeably to Dr. Hutton's theory of the formation of clouds, to the intermixture of contrary currents of air of different temperatures, severally saturated, or nearly saturated with humidity. Hence, if clouds be newly formed, and particularly if their formation be sudden, as by the intermixture of contrary currents, their temperature ought to be higher than that of the atmosphere at a similar height.

2*nd*. Clouds obstruct and absorb the radiating calorific stream caused by the influence of the sun during day, and thereby, in a great measure, prevent its warmth from reaching the subjacent earth. In like manner, they obstruct and absorb the radiating calorific stream in its retrocession from the earth during night; and, in the absence of the sun, assist in retaining that heat which its presence communicates, and which is so necessary to the preservation of the vegetable, and the comfort of the animal creation.

It is obvious that if clouds obstruct and absorb the rays of the sun during day, their temperature must be thereby augmented. And a very little consideration will show, that by the nocturnal retrocession of caloric from the earth, their temperature must be also increased, or at all events, must be prevented from sinking so much as it would otherwise do. Supposing a cloud to be of the same temperature as a clear portion of the atmosphere at a similar elevation, when caloric in the evening reverses its course, and begins to radiate from the earth's surface; it is evident, that if the radiant caloric is not permitted to pass through it with the same celerity as it would do through a similar amount of space containing no cloud, the portion which is detained, absorbed, and accumulated, must raise the temperature of the cloud more than it raises that of a clear atmospheric space at a similar elevation, by which it is neither detained nor absorbed, and wherein, of course, it is not accumulated. Hence, it may be inferred, that clouds, not only during their formation, but ever afterwards, both by day and night, are subjected to sources of increased temperature, beyond that of the pellucid atmosphere at a similar height. And admitting their temperature to be somewhat raised by such means, I conceive it probable, that the heat thus accumulated, partly from the immense volume of clouds, and partly from their floating along with the same atmospheric stratum, is not liable to be so soon dissipated as might at first be imagined.

But, agreeably to the principle of the best absorbers being also the best radiators of caloric, it might be objected, that though clouds may become warmer than the pellucid atmosphere at a similar elevation during day, when all bodies are rising in temperature; still, they ought to become colder during night, when all bodies are sinking in temperature, just as the earth's surface becomes warmer during day, and colder during night, than the incumbent atmosphere. In weighing this objection, it ought to be recollected, that it is merely the surface of the earth that becomes colder than the incumbent air during night. The ground, even so little as an inch below the surface, is almost always warmer during night than the air, sometimes, especially on calm clear nights, by as much as from 5 to 10 degrees. Upon analogous principles it may be therefore inferred, that the temperature of the body of a cloud could be but little affected by the coldness of its upper surface. But it may be farther remarked, that though the upper surface of a cloud, by radiating its heat during night, may become colder than a clear portion of the atmosphere at a similar elevation; still, its lower surface, which is then receiving radiant caloric from the earth, ought to be warmer. Besides, the temperature of the upper surface of a cloud will be prevented from sinking in any considerable degree, by the condensation of additional vapour into cloud, and the evolution of heat that must thereupon ensue, just upon the same principle, as the coldness of the earth's surface occasioned by radiation during night, is mitigated by the evolution of heat that accompanies the condensation of the watery vapour contained in the lower portion of the atmosphere, and its precipitation in the form of dew.

But without pursuing this hypothetical, and perhaps unimportant argument farther, or attempting to trace the effect of the slow communication of the temperature of one portion of a cloud to another, by means of the descent of its cold superior strata, and the ascent of its warm inferior strata; it may be reasonably concluded, from the circumstance of clouds partially absorbing, and interrupting radiant caloric, both in its progress towards and from the earth, as well as from the evolution of heat that attends their formation, that their temperature during night, is usually several degrees higher, than that of a clear portion of the atmosphere at a similar elevation; and that their never-failing influence in retarding the velocity of the radiating calorific stream underneath, and thereby in counteracting the radiation of heat from the earth's surface during night, is partly to be ascribed to this cause. The circumstance of clouds being at one, two, or three miles' distance from the earth's surface, does not by itself essentially affect the principle of the argument. An accumulation of caloric, however distant, by means of its repellent force, will communicate a calorific repulsion, and a consequent diminution in the velocity of the radiating stream, backwards to the earth's surface, as instantaneously as the moving velocity of radiant caloric is propagated forwards.

In certain circumstances, it is possible, that the supervention of heated clouds during night, may not only impede, but for a time may even reverse the direction of the calorific current, and cause it to move towards the earth's surface, just as the oceanic tide is seen to impede, and reverse the course of a stream, in its progress towards the ocean. In other circumstances, the reversion of the calorific current may not extend so far as the earth's surface. The intermediate atmosphere may have been previously chilled; and the supervening cloud, and the earth's surface, may continue for sometime to radiate heat into it in directions opposed to each other. In this case, the accumulation of caloric, and the increase of temperature of the intermediate atmosphere, will be accelerated by the simultaneous separation, and commixture, of radiant heat from the cloud and from the earth, just as the rising of the tide, in the other instance, is promoted by the double source from whence water is supplied.

From the preceding observations, the reason why clouds counteract the appearance of cold, and the formation of dew on the earth's surface, is obvious. During night, when the sky happens to be clear, the radiating calorific stream, in its retrocession from the earth, meets with little or no interruption; and caloric, in obedience to the preponderance of calorific repulsion, radiates from grass, and other good radiating surfaces, with greater rapidity than it is supplied by slow conducting materials from underneath. Hence, the temperature of such surfaces sinks; and by communicating their coldness, and a consequent diminution of capacity for humidity to the portion of the atmosphere in immediate contact with them, causes that precipitation of moisture which has received the name of dew. On the contrary, when the sky is o'ercast with clouds, the retrocession of the heat, which the earth had previously absorbed during day, is retarded; and the slow conducting materials of the earth become able to supply caloric to its surface, even when the temperature of the surface is as high as that of the incumbent atmosphere, as fast, or nearly as fast, as it radiates from it. Hence, in such circumstances, the temperature of the radiating surface does not sink, or, at all events, does not sink so much as it would otherwise do; and of course can communicate little or none of that coldness to the contiguous portion of the atmosphere, which is necessary to the precipitation of dew. Or supposing that the sky had been clear, and had thereafter become cloudy, the coldness of the surface, which the former condition had occasioned, would soon disappear. The conduction of heat from the inferior strata, is accelerated as the coldness of the surface increases; and accordingly, when the rapidity with which heat radiates from the surface is diminished by the supervention of clouds, the temperature of the surface, if previously chilled, will continue to rise, till the amount of heat that separates from it by radiation and otherwise, and the amount supplied to it from underneath, by conduction and other sources, (such as by the heat evolved during the deposition of dew,) become equal.

In this manner, the differences of temperature subsisting at night between radiating surfaces, and the incumbent atmosphere a few feet above the ground, are determined by the point at which the supply and the consumption are equalized. When the amount of caloric that separates from any radiating surface, is greater than the supply from all sources taken together, the temperature of the radiating surface sinks below that of the incumbent atmosphere, till the supply which increases, and the consumption which diminishes, with the coldness produced on the earth's surface, become equal. And, *vice versa*, when, from any cause, such as the temporary supervention of clouds, the supply becomes greater than the amount that separates from the previously chilled radiating surface, the temperature of the radiating surface rises, and the difference between its temperature, and that of the incumbent air, continues to diminish, till the supply, and the consumption, are again equalized.

Explanation of the Gradual Rise in the Atmospheric Temperature, during Serene Nights, from the Surface of the Ground upwards, to the Height of 220 *Feet.*—Another fact, mentioned by Dr. Wells, is the gradual rise in the atmospheric temperature, during serene nights, from the surface of the ground upwards. He ascertained himself that this was the case to the height of nine feet, this being the highest point upon which he experimented. It farther appears, from the observations of Mr. Six of Canterbury, noticed by Dr. Wells, that the temperature continues to increase to the height of 220 feet; and how much further is unknown, for Mr. Six's observations were not carried higher. On calm clear nights, Mr. Six often found the atmospheric temperature as much as 10 degrees warmer at 220 feet above the earth's surface, than it was at seven feet; but on cloudy nights, instead of being warmer, he found it sometimes colder at the greater height. Now 10° added to 15°, which was the greatest difference observed by Dr. Wells, during serene nights, between the temperature of grass-plat, and that of the atmosphere four feet above it, makes a total difference of 25 degrees of Fahrenheit. And Dr. Wells even supposes, that on a large plain remote from any city, and free from objects of every kind that are elevated above the ground, and in a country remarkable for the dryness of its air, all which circumstances, he says, may be found in Russia during winter; a difference of at least 40 degrees, between the temperature of the earth's surface, and that of the atmosphere between 200 and 300 feet above it, may, during night, arise from radiation. Such a sudden transition in the temperature of the air near the ground from what it would be during the previous day; and such an intense degree of cold as would be thereby occasioned in a cold climate, during the winter season, satisfactorily accounts for the great mortality that took place, on several nights, during the disastrous retreat of Bonaparte's army from Moscow, in 1812.

This gradual increase of the atmospheric temperature, or in other words, this gradual propagation of the coldness of the surface of the ground, during serene nights, upwards to the height of 220 feet, as above related, is very imperfectly accounted for by Dr. Wells. After having endeavoured, at considerable length, to prove a fact that hardly requires proof, viz. that air is capable in some degree both of absorbing heat which is radiated into it, and thereupon of becoming warmer, and of radiating heat, which had before formed a part of its temperature, and consequently of becoming colder, he introduces Prevost's theory of radiation to explain the phenomena. "When, therefore," says Dr. Wells, "the earth has become colder, from radiation, than the neighbouring air, in consequence of the latter having, by reason of its small radiating power, emitted a less proportion of its heat to the heavens, the warmer air must radiate a part of its heat to the earth, without receiving a full compensation, and will, therefore, become colder than it would otherwise have been. In proportion, too, as the air is nearer to the earth, must the cold of the former, from this cause, be the greater. My own conception of this matter is facilitated by contemplating the occurrence of an opposite effect, when the earth is warmer than the air." And as an addition to this sentence, the reader is referred by an asterisk to a note at the bottom of the page, in which he says, "The same facility is afforded by considering cold as a body;"—an erroneous notion that has been long exploded.

The explanation above quoted is obviously unsatisfactory, and yet to give one that is satisfactory, which we will now endeavour to do, is a task of some difficulty, and one that has never yet been accomplished.

It requires little acuteness to perceive, from the facts we have related, that the phenomena result from a gradual communication upwards, of the coldness of the radiating surface underneath; and it is easy to add, that when the earth's surface has become colder by radiation than the incumbent air, the temperature of the latter will be more slowly, and in a less degree, affected by the superior coldness of the former, according as it becomes more distant from it. Still, however, the difficulty of explaining how the coldness on the earth's surface, during serene nights, is communicated 220 feet upwards, remains unsolved. It evidently cannot be by the rising of the inferior strata; for they being coldest, are specifically heaviest. It cannot be by conduction; for air is one of the slowest conductors of caloric, and a few degrees of additional temperature at the height of 220 feet, could not thereby so speedily affect the temperature of the subjacent strata, as to produce, in the course of an hour or two, a gradual decrease of warmth down to the ground. Neither can it be by the radiation of the heat contained in the atmosphere towards the earth's surface. Though the communication of the coldness of the surface upwards, be a consequence of the coldness underneath; still, it is so far a simultaneous attendant, that the abstraction of heat from the incumbent atmosphere, at first from the portion nearest the ground, and thereafter gradually ascending, commences so soon as the temperature of the surface underneath begins to sink. Of course, if the atmosphere to the height of 220 feet radiates heat downwards in greater proportion, according to its proximity to the earth, at the time the surface of the ground is radiating heat upwards, there must, in conformity with Prevost's theory of radiation, be two opposite calorific currents flowing at the same time and place, which we regard as mechanically impossible. According to our notions of the distribution of caloric, and of its slow movement in the act of radiation, such an explanation would imply that contiguous calorific particles diffused throughout the atmosphere, though, from their proximity and similarity of situation, necessarily subjected to the same forces, begin to move partly upwards, and partly downwards, without regard to the preponderance of impulse. And if we were farther to imagine, in conformity with Prevost's theory of radiation and likewise adopted by Dr. Wells, that these calorific particles, the instant they begin to move, are projected upwards and downwards with the same determinate inconceivable velocity, without regard to the degree of force by which they are either impelled or resisted; we only mend the explanation, by farther confounding it with an additional mechanical impossibility.

Before attempting to give an explanation of the phenomena under consideration, it will be necessary, in order to prevent misapprehension, to re-advert to a subject previously noticed, viz. the division of the caloric contained in the atmosphere into two portions; one of which we denominated the intermediate or free caloric; the other, the caloric held in affinity by the ponderable bases of gaseous particles. The former of these portions being that which alone radiates; the latter being that which floats along with the particles by which it is held in affinity. Now, though we have thus spoken of caloric as being divided into two portions, there is in reality no permanent or distinct separation existing between them. The temperature of the atmosphere is determined by their united influence. They are reciprocally convertible into each other; and their separate amounts are so mutually dependent, as to increase and diminish together, according as the temperature of the atmosphere rises and sinks. If the radiating portion were to be suddenly diminished in quantity, a part of that which was previously held in affinity instantly separates from the aerial particles to which it was united, and forms part of the radiating portion. And, upon the same principle, if heat be radiated into the atmosphere, and its temperature rises, a part of the supply of radiant caloric will have united with the gaseous particles, and increased the non-radiating amount held in affinity by them; while another part will have increased the amount of the radiating portion. Supposing this point understood, we will now resume the consideration of the subject immediately before us.

During night, the side of the earth, by being turned away from the sun, is subjected to a diminished calorific repulsion, in comparison to what it was during the previous day. Of course, in obedience to the preponderance of calorific pressure, the whole of the free caloric contained in the atmosphere, from the surface of the ground, radiates upwards, in the direction soonest calculated to restore that distribution of caloric around the earth, which would ultimately take place, provided the sun were annihilated: the rapidity of the movement at any given point, being proportional to the impulse including the acquired velocity, less the resistance. From the surface of the ground caloric also radiates, with a rapidity increasing with the superiority of its temperature above the point at which the calorific equilibrium would be established; and also, according to the fitness of its surface for radiating caloric. During this general retrocession of caloric from the inferior atmospheric strata, and from the surface of the earth, the temperature of the different superior atmospheric strata while radiating caloric, is prevented from sinking to what, in such circumstances, is relatively natural to them, by the supply which they are simultaneously receiving from the inferior strata; just as the bed of a river, while the water which covers it is retiring, is prevented from becoming dry, by the supply which it is simultaneously receiving from the current behind. If, however, any atmospheric stratum, or any space through which the receding calorific stream is passing, should receive less caloric than it parts with, its temperature must necessarily sink. Now, this is the case at the surface of the ground. Caloric is there supplied from underneath, by conduction, more slowly than it separates from it by radiation; and from the circumstance of the best radiators of caloric being its worst conductors, the sinking of temperature is greater, according to the fitness of the surface for radiating caloric.

Here it might be supposed, that the farther explanation of the phenomena was simple; that the surface of the ground being the place where the supply of caloric becomes deficient, the temperature of each stratum of air, according to its proximity to that surface, must be proportionally sooner, and in a greater degree affected by the deficiency of supply. But this supposition will not explain the phenomena. The coldness of the incumbent atmosphere is found to be proportional, not to the smallness of the quantity of caloric which it receives in a given time from the subjacent ground, but to the existing coldness on the surface of that ground. And unless the coldness on the surface of the ground appears, though the amount of caloric which the air receives from it be ever so small, there is no coldness communicated to the incumbent atmosphere. And *vice versa*, if the coldness on the surface of the ground appears, though the amount of caloric which the air receives from it be ever so great, it is always communicated to the incumbent atmosphere. We will illustrate this point by supposing a case. Let two metallic plates be laid during a serene night upon grass-plat, the upper surface of the one being polished, and that of the other tarnished. Upon the surface of the former very little cold makes its appearance, and little dew is deposited, when compared with the surface of the latter; and though, in the same time, the latter allows a greater amount of the heat of the subjacent earth to pass through it than the former, still the air above the latter is most cooled. Hence it may be concluded, that the coldness communicated during serene nights to the atmosphere, and which diminishes gradually to the height of 220 feet, arises directly from the coldness resulting from radiation on the surface of the ground itself; and not from the smallness of the supply of caloric, which the incumbent atmosphere, in a given time, thence receives.

The only plausible manner of explaining the phenomena under our notice which occurs to me, is founded upon the principle, that the amount of caloric which any ponderable body, or particle, in recovering an equilibrium of calorific tension, can hold in affinity, is proportioned to the amount which contiguous bodies or particles hold, relative to their several capacities, and relative also to their several powers of obstructing the movements of caloric. Accordingly, when the temperature of grass-plat on the earth's surface sinks, contiguous gaseous particles become unable to retain so large an amount of caloric in affinity, as they previously did. The external calorific repulsion in the direction of the earth's surface underneath being diminished, a portion of the caloric, previously held in immediate affinity by incumbent gaseous particles, separates from them, and becoming a part of the intermediate radiating portion, moves slowly upwards with the calorific current. Upon the same principle, each stratum of air, from the surface of the ground upwards, becomes successively affected by the sinking of temperature, and the diminished calorific tension of that which is underneath; and a similar separation, and escape by radiation, of a portion of the caloric which it previously held in affinity, takes place; and thus a gradual sinking of temperature is propagated upwards. Such appears to me to be the most likely mode, in which the coldness on the surface of the ground, arising from radiation during serene nights, is communicated, according to some unknown decreasing ratio, to the height of 220 feet, and how much farther has not been ascertained. I will only add, that it is possible, that the phenomena may be partly owing to a slight degree of agitation, and commixture of the different atmospheric strata, in consequence of the unevenness of the surface of the ground disturbing the progressive motion, to which the air, even in the stillest nights, is subjected.

Explanation of the Radiation of Caloric from the Surface of the Ground, when the incumbent Atmosphere to a great Height is warmer than that Surface.—The only other difficulty connected with this subject, that requires consideration, and which has hitherto defied all attempts at explanation, is the fact of caloric radiating from the cold surface of the ground, and from the cold air near its surface, in the direction of the warmer atmosphere above. The reason of this apparent contradiction to the principle formerly laid down, viz. that heat radiates only from hot towards relatively cold bodies, I would refer to the circumstance of the movements of caloric being determined by the aggregate influence of calorific repulsion, and not by one that is partial and circumscribed. Though the particles of free caloric, a few feet from the surface of the ground, may experience less repulsion from the smaller amount of caloric contained in the air within a yard beneath them, than they do from the greater amount within a yard above them; still, the aggregate preponderance of calorific repulsion to which they are exposed, and by which their movements are at all times directed, may, notwithstanding, be such as to propel them from the earth's surface.

Caloric, agreeably to the law of distance, repels caloric, whether near or distant, with a force diminishing as the square of the distance increases; and, agreeably to the law of mass, with a force increasing directly with its quantity. Each particle of caloric is subjected to calorific repulsion on every side; but it is only the preponderance of force, including both that which is exerted by near and by distant caloric, which directs its radiating movement. Hence, in the case we are considering, it is presumable, that though the preponderance of repulsion exerted upon caloric, by caloric contained within the circumference of a few feet, might cause it to move towards the earth; still, the aggregate unneutralized repulsion of both near and distant caloric, exerted according to the law of mass and distance, preponderates, so as to communicate a calorific radiating movement from the earth.

The phenomena presented by the radiation of caloric from and towards the earth, are precisely analogous to what takes place during the heating and cooling of bodies around us. If two thermometers, the one with its bulb covered with a thin coating of lamp-black, and the other naked, be heated or cooled from a given temperature, higher or lower than that of surrounding bodies, to an equality with them; the one with the blackened bulb, having its absorbing and radiating power thereby increased, will both heat and cool faster than the other. If we suppose the atmosphere in the apartment also simultaneously subjected to the cooling or heating process, as might be conceived to result from the introduction of a quantity of snow, or of melted lead; and, for the sake of analogy, let us farther suppose the snow or the melted lead suspended along the ceiling of the apartment, and the thermometers laid upon a carpet covering the floor. In this case, both thermometers will cool and heat faster than the air immediately above them; and the one with the blackened bulb, with greater rapidity than the other. And, judging from analogy, I farther conceive, (for I am not aware of the fact having been proved by experiment,) that the temperature of the air at the surface of the carpet, like on the surface of grass during serene nights, will be sooner, and to a greater degree affected, by the cooling and heating processes, than the air a foot or two above it. Hence, the general principle applicable to the cooling and heating processes connected with radiation, either in reference to bodies individually, or to a hemisphere of the earth, is, that the surface of solids and liquids cool and heat faster than gaseous substances, such as the atmosphere, through which caloric radiates; and the surface of different solids and liquids cool and heat with greater rapidity, according as their radiating and absorbing powers are stronger. The cause of this general principle can only be referred to the preponderance of calorific repulsion being stronger, when the temperature is sinking at the surface of solids, than it is in the atmosphere exterior thereto; and to the slowness with which heat passes through solids by conduction. The amount of caloric that constitutes the excess of temperature within a given distance, say half-an-inch from the surface of a solid internally, and which it has to part with before the calorific equilibrium can be restored, may be much greater than the amount of caloric constituting the excess in the atmosphere, within the same distance of the surface externally.

The following fact, stated by Dr. Wells, harmonizes with the explanation now given:—"I have always found," says Dr. Wells, "on dewy nights, the temperature of the earth ½ an inch, or an inch beneath its surface, much warmer than the grass upon it. On five such nights the differences were from 12 to 16 degrees. The earth, at the above-mentioned depth, was also almost constantly warmer on dewy nights than the air; sometimes it was considerably so, for I once observed it to be 10° warmer, at another time 9°, and at a third 7½°. An exception will no doubt occur, if very mild weather should follow a long frost; but of this I have had no experience."

Evidence afforded by the preceding Facts and Explanations, in confirmation of our Theories, relative to Centrifugal Force, and Solar Radiation.—In concluding the subject of radiation, it may be remarked, that the circumstance of the surfaces of solids heating and cooling faster than the air by which they are surrounded, when temperature is either rising or sinking, demonstrates that the repulsion exerted by caloric towards caloric, is not restricted to insensible, but extends to sensible, and even considerable distances. It also demonstrates, that the direction in which caloric moves by radiation, is determined by the aggregate repellent influence of caloric, whether near or distant; and not by the influence only of that which is near. Were this not the case, it would be impossible to account for heat radiating upwards from the surface of the earth, when the atmospheric strata immediately thereupon incumbent, are warmer than that surface. And also impossible to account for the surface of solids heating and cooling by radiation, faster than the air by which they are surrounded, when a general rise or reduction of temperature is going on.

That the particles of mutually repulsive imponderable materials repel each other at all distances, in the same manner, and according to the same law, as the mutually attractive ponderable particles attract each other, is indirectly confirmed by the explanation now given of the phenomena we have been last considering. It is also confirmed by the explanation previously given of the difference in the force of calorific radiation, towards and from the earth's surface, in different latitudes. And if it be admitted, that caloric repels caloric at sensible, and even considerable distances around us; there can be no doubt that caloric, and other calorific repellent imponderable materials, contained in the sun, also repel caloric, and other imponderable materials contained in the earth. And this, be it recollected, is the fundamental principle of the theories we have advanced, in order to explain the nature and cause of centrifugal force, and solar radiation.

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SECTION XXXV.

ON THE CAUSES WHICH DETERMINE THE DISTRIBUTION OF CALORIC.

Before concluding this volume, we purpose to inquire into the nature of the theory, now almost universally adopted, which supposes that the central parts of the earth are in a state of intense ignition; and that the globe, as a whole, has undergone, and is still undergoing, a gradual reduction of temperature, in consequence of this interior central heat effecting its escape, by slowly penetrating the crust of the earth, and diffusing itself into celestial space by radiation. With the view of rendering the exposition, to be given in the following Sections, of the error committed by geologists in reasoning on this subject, as intelligible as possible; as well as to enable me distinctly to explain what I conceive to be the real nature and cause of the interior heat of the earth, which geologists have been so much puzzled to account for, I purpose, in the first part of this Section, to restrict myself to some preliminary inquiries regarding the causes which determine the distribution of caloric within the surface of the earth; and towards the conclusion shall so far digress from our subject, as to take the opportunity of extending the investigation to the celestial spaces throughout the universe. It may be also premised, that though these preliminary inquiries, as well as those which they are partly intended to elucidate, and introduce, may be considered as totally unconnected with the subjects previously treated of in this volume; still, on reflection, it will be perceived, that unless we can show that the notion at present almost universally received, of central heat penetrating the crust of the earth, and escaping for ever by radiation from its surface, is erroneous; that very notion may be urged in refutation of the views which have been advanced in our previous treatises on Centrifugal Force, and Calorific Radiation.

On the Causes which Determine the Distribution of Caloric within and around the Earth's Surface.—It has been already stated, that ponderable materials, by means of mutual attraction subsisting between their particles, are concentrated into those aggregate revolving masses, which have been denominated suns, stars, planets, satellites, and comets. And were attraction the only force existing in nature, these ponderable or mutually attractive materials could only exist as solid, cohering, and incompressible masses, and all the different celestial orbs in the universe, would rapidly concentrate into one.

In like manner, the distribution of caloric must evidently be determined by the conjoint influence of the forces inherent in, or acting upon it. Provided repulsion subsisting between its particles were the only force by which it was actuated, caloric would distribute itself equally throughout unoccupied space. Its particles would mutually repel each other, till the pressure of repulsion was equal in every direction; and this could only take place, when they were at equal distances from each other. But as caloric, in addition to repulsion subsisting between its particles, is attracted by all ponderable materials; and as these, as above stated, are concentrated by their mutual attraction into suns, stars, planets, satellites, and comets; it is obvious, that caloric cannot exist in a state of equal diffusion, but must be concentrated in greater or less proportion by each of these aggregate revolving masses, according as the attractive influence which they severally exert towards it, overcomes its repulsive tendency to diffuse itself equally.

The state of division in which caloric and the other imponderable bodies exist, is extremely obscure, and somewhat incomprehensible. From being possessed of an inherent repulsive force towards homogeneous matter, they have within themselves the principlé of infinite divisibility.

And as the properties of matter are indestructible, and inseparable from the matter itself; and as the degree in which matter is divided must be determined by the forces inherent in, or acting upon it; it follows, that imponderable bodies cannot of themselves cohere in parts, or particles, that have any degree of extension whatever: for no degree of smallness, or division, can deprive them of that inherent repulsive property which causes division. Our reasoning powers here lead us to believe, that all imponderable matter exists in a state, which, to our minds, as at present constituted, is utterly inconceivable. Conception, considered as a mental faculty directed to the contemplation of material existence, is limited to objects cognizable by some one or other of our five senses. But matter so divided, that its parts have no extension, and which are therefore unsusceptible, even to imagination, of farther division, or diminution, supposes a condition of material existence, destitute of every sentient quality, by which any distinct conception of it can be formed. Nevertheless, though the terms particles, and atoms, (which signify small but distinctly separate portions of matter,) may appear inappropriate, when applied to substances supposed to exist in a state of infinite division; still, as we have none that are either more precise, or more explanatory of our meaning, we have been obliged to adopt them.

Caloric, by means of its attraction for ponderable materials, is usually said to unite with them in every proportion, in contradistinction to definite proportions. This characteristic, though true chemically speaking, must be taken, in a physical sense, with a degree of limitation. As the particles of caloric are mutually repellent, ponderable particles will be able to attract caloric, and retain it in affinity, only to the extent that the attractive force subsisting between them and caloric, overcomes the diffusive tendency, resulting from repulsion subsisting between the particles of caloric thereby concentrated. When the amount of caloric concentrated becomes so great, that the repellent force subsisting between its particles, is an exact counterpoise to the attraction exerted towards it by the ponderable particles, such ponderable particles may be said to be saturated with caloric, and their attraction for it can concentrate no more.

Caloric, by means of its attraction for all ponderable substances, operating in conjunction with an inherent repellent property towards matter of its own kind, which causes it to exist in a state of infinite division, is enabled to penetrate, and pervade, all aggregate revolving masses of ponderable materials; and to distribute and intermix itself with the concentric layers of which they are composed, in proportions which must be everywhere determined by the conjoint influence of the forces which act upon it. And when caloric is distributed amongst ponderable bodies, and spaces, (whether containing ponderable matter or not,) so that the amount of it in given spaces, is everywhere proportioned to the conjoint influence of the attractive, repulsive, and compressing forces, which act upon it in these spaces; it may be said to exist in a state of rest, or equilibrium; and, in such circumstances, can have no tendency to move, either by conduction, or radiation, in any direction whatever. So soon, however, as that state of rest or equilibrium is disturbed, caloric, in obedience to the preponderance of forces acting upon it, begins to move in the direction calculated to produce, and restore, that distribution in which its equilibrium, and state of rest, consists.

It has been supposed, that what is called equality of temperature, indicates the existence of, and is synonymous with, that distribution of caloric, in which its equilibrium and state of rest, consists; and that any inequality of temperature, invariably denotes a disturbance of the calorific equilibrium, which necessarily produces a movement of caloric, from the bodies or spaces where temperature, as indicated by a thermometer, is highest, to where it is lowest. We shall endeavour, by and bye, to show, that though this be true in reference to contiguous bodies and spaces similarly circumstanced; it is not true in regard to the successive concentric layers of ponderable matter, more and more condensed by the increasing weight of superincumbent strata, as we descend from the surface to the centre of a globe, or sphere, such as the earth. This oversight lies at the foundation of the erroneous conclusions of geologists on the subject of central heat; and when pointed out, will give us an insight into its nature and cause. It will also afford us the means of showing, that though the temperature of the earth, as indicated by a thermometer, may increase from the surface to its centre; still, it is an error to suppose that the globe is undergoing a gradual reduction of temperature, in consequence of that interior heat slowly penetrating its crust, and escaping for ever by radiation from its surface.

The relative amount of caloric absorbed by different substances estimated by weight, in raising them from one given temperature to another, has been called their capacity for caloric, or their specific heat; and tables of these differences, taking air or water as unity, are usually inserted in chemical works. From these tables it appears, that the calorific capacity of bodies, estimated as usual by weight, is exceedingly diversified. Thus, hydrogen gas possesses a calorific capacity sixteen times greater than the same weight of oxygen.

The calorific capacity of all bodies existing in the gaseous or elastic state, under the same pressure, seems to be strictly proportional to their bulk. But if we except gases and vapours, it appears that the specific heat of bodies estimated by bulk, is also exceedingly diversified. For instance, when the calorific capacity of gases is compared with that of liquids or solids, estimated by bulk; or when the calorific capacity of similar bulks of different liquids, or different solids, are compared together, there appears to be no strict relation between their specific heats. Thus, the specific heat of water is much greater than that of air, of the usual density, not only when estimated by bulk, but even when estimated by weight. If we reckon the specific heat of water 1·0000, the specific heat of the same weight of air is only 0·2669. The specific gravity of alcohol is considerably less than that of water; and yet, if we reckon the specific heat of water 1·000, that of alcohol is only ·602. In like manner, bismuth, lead, and gold, are specifically lighter, and, notwithstanding, have a less specific heat than platinum. But though no strict relation subsists between the density and specific heat of bodies individually considered, except they exist in the gaseous or elastic state; still, if they be taken in classes, there appears to be a general approximation to the law, that as bodies increase in density, their specific heat estimated, as usual, by weight, diminishes. Thus, metals are the densest class of substances, and they have the least specific heat.

From experiments it likewise appears, that the calorific capacity of bodies estimated by weight, is diminished by condensation, whether produced by the combination of substances possessed of a chemical affinity for each other, or by mechanical pressure. For instance, upon mixing sulphuric acid and water, chemical combination ensues, accompanied with increase of density, evolution of caloric, and a diminution in the specific heat of the compound, below the mean of the two substances of which it is composed. Gaseous substances, upon being suddenly condensed by mechanical pressure, and metallic substances, during the process of hammering, evolve caloric, and have their specific heat thereby reduced.

A difference in the condensation of fluids and solids may be here adverted to. Fluids, upon the removal of the compressing force, immediately absorb an amount of caloric similar to that which they parted with during compression; and, accordingly, resume both their former specific gravity, and specific heat. Metals, on the contrary, and also non-metallic solids, remain condensed after the removal of compression; and do not recover either their former specific gravity, or specific heat, until heated to redness, or until reduced to fluidity by heat. Consequently, the specific heat of solids, and, of course, the absolute amount of caloric which they contain at a given temperature, is permanently diminished by condensation.

Now, admitting repulsion subsisting between calorific particles, to be a definite force, increasing directly with the quantity concentrated in a given space, and inversely with the square of the distance at which the calorific particles repel each other, the different specific heats of different bodies can only be explained upon the supposition, that the different elementary ponderable substances exert different definite degrees of attractive force for caloric; and, consequently, are thereby enabled to concentrate different proportions of it in a given space, in opposition to its own definite repulsive tendency to diffuse itself equally. And as condensation of all ponderable materials, whether effected by mechanical pressure, or chemical combination, is invariably attended with the evolution of caloric, and a diminished capacity of such materials for retaining it in affinity, we see that the distribution of caloric, and the amount of it contained in a given space, among terrestrial materials, must be farther modified and rendered unequal, not only by the inequality in the attractive force which the different elementary substances exert towards it, but also by the unequal degrees in which these elementary substances are condensed by mechanical pressure, and chemical combination.

In descending perpendicularly from the surface to the centre of the earth, each concentric layer of ponderable matter must be compressed by the superincumbent weight of all those that are exterior. And as this superincumbent pressure increases with the depth, the condensation thereby produced, or, in other words, the number of ponderable particles thereby condensed into a given space, must, in some ratio or other, be gradually augmented. Now, as the attractive force which one kind of matter exerts towards another is a constant quantity, and as the number of ponderable particles in a given space, severally exerting a definite attraction towards caloric, are gradually increased by condensation, in descending perpendicularly towards the earth's centre; it follows, that the amount of caloric thereby concentrated into a given space, in opposition to its inherent repulsive tendency to diffuse itself equally, should also be increased in descending towards the earth's centre. And, but for the modifying circumstance next to be mentioned, the ratio of increase should be strictly proportional to the increase of density of the ponderable materials by which it is attracted.

But, then, it has been ascertained by experiment, that artificial condensation of ponderable materials, whether effected by mechanical pressure or chemical combination, is invariably attended with the evolution of caloric, and a diminution in the calorific capacity, or specific heat, of such materials. Hence, from analogy, it might be concluded, that atmospheric compression, or rather, (for it applies to all matter as well as air,) the incumbent weight or pressure of all external strata of ponderable materials upon those that are interior, should produce a similar effect with artificial condensation, in expelling caloric permanently from all such materials, in the same proportion as it diminished their specific heat. We shall see, however, in the next Section, that, owing to an overlooked compensating cause, the compressing influence of external strata of ponderable matter, has somewhat less effect in diminishing the absolute amount of caloric contained in interior strata of ponderable matter, than it has in diminishing their specific heat. And that this is the fact, is evident, from the progressive rise of temperature, observed in descending from the surface towards the centre of the earth. Judging, however, from the fact of caloric free to move by radiation, being attached in the form of an atmosphere around the earth, in opposition to its inherent repulsive tendency to diffuse itself equally throughout unoccupied space, I am inclined to think, that the compensating cause above alluded to, only in part compensates the effect of condensation, in expelling caloric from the interior strata of the earth. Now, if it be admitted, in conformity with this latter supposition, that the same number of ponderable particles are unable to retain in immediate affinity to their surfaces, the same amount of caloric, when they are condensed into a smaller space in the interior of the earth, as they would do if uncondensed; it follows, consistently with the principle that forces are permanently inherent in matter, and that they act at all distances according to the law of distance, that in proportion as each interior concentric layer of ponderable materials, in descending from the surface to the earth's centre, is deprived of a greater proportion of caloric by condensation, than the one exterior to it, so must it be exerting a stronger unneutralized or unsatisfied attraction for caloric. One effect of this unneutralized or unsatisfied attraction exerted upon caloric by the condensed central portions of the earth, must be to retain a portion of caloric around the earth in the form of an atmosphere, probably extending considerably beyond the boundaries of the aerial atmosphere. Another effect must be to increase the quantity of caloric intermixed with the aerial atmosphere, and with the superficial and less condensed strata of the earth, beyond what their own unassisted attraction for it would be able to retain in immediate affinity. And it need hardly be remarked, that our limits of actual observation downwards, when the magnitude of the earth is considered, can scarcely be said to extend beyond the surface of these superficial and less condensed strata.

It might be supposed that the unsatisfied attraction exerted by the condensed central portions of the earth towards surrounding caloric, might render it susceptible of being weighed. This, however, is not the case. In consequence of caloric penetrating and pervading all ponderable materials, it is enabled to maintain its equilibrium, by distributing itself among the different concentric layers of the earth and atmosphere, in amounts everywhere proportioned to the united influence of the forces which act upon it. If the calorific equilibrium were disturbed, heating a body should either increase or diminish its absolute weight, according as that disturbance caused caloric to sink into the earth, or to separate from it. But heating any ponderable body, when the caloric which surrounds it exists in a state of equilibrium, can neither increase nor diminish its absolute weight; because the accumulated caloric, in such circumstances, can have no more tendency to gravitate from, than towards the earth's centre. And when it is considered that the weight of a body at the earth's surface, is only diminished by a 12,868,200th part, by the sun's attraction vertically exerted; it can hardly be supposed that the disturbances of the calorific equilibrium, produced by the sun's influence during the alternations of day and night, and summer and winter, and which are limited to the atmosphere, and to the depth of 40 feet below the surface of the ground, can ever be so great, as to cause the heating or cooling of bodies to affect their weight, in any degree, that could be appreciated in experiments, however carefully and scientifically conducted.

In order to render this portion of our subject better understood, we may here so far recapitulate, as to give an abridged statement of the distribution of terrestrial caloric, which we conceive must result from the forces which act upon it.

When treating of the Solar Radiation of Heat, in Section XXVI., we pointed out the influence the sun has had, and continues to have, in permanently, and periodically, modifying the distribution of caloric in different latitudes of the earth. If, by way of avoiding perplexity, we leave the sun's influence out of consideration; the distribution of terrestrial caloric may be said to be effected by means of three forces, the conjoint influence of which everywhere determines its amount in a given space. These forces are as follow:

1*st.* Repulsion mutually subsisting between calorific particles, with which we also include repulsion supposed to subsist between caloric and other imponderable bodies.

2*d*. Attraction for all ponderable particles; and this force must act more or less powerfully, not only according as the attractive influence of different kinds of ponderable particles varies in strength, but also in proportion to the quantity of such particles condensed into a given space.

3*d*. The influence which the pressure of external strata of ponderable materials concentrated into spheres, such as the sun and earth, has in condensing those that are interior, and in expelling a portion of the caloric which they would otherwise retain in immediate affinity.

By means of the first of these forces acting by itself, caloric would diffuse itself equally throughout unoccupied space. By means of the two first forces acting together, caloric should be more or less concentrated by celestial orbs, and correspondingly diminished in quantity in other spaces, according as its attraction for these aggregate revolving masses counteracted the repulsion mutually subsisting between its particles. And as the ponderable matter by which caloric is attracted becomes denser, or in other words, increases in amount in a given space, from the surface to the centre of the earth, it may be inferred, that the amount of caloric, in a given space, likewise increases from the surface to the centre of the earth. From the influence of the third force acting in conjunction with the other two, it may be inferred, that though the amount of caloric in a given space, (so far internally, at least, as observation extends,) and especially temperature, by which that amount is usually, though very incorrectly, estimated, may increase from the surface towards the centre of the earth; still, judging from the fact before mentioned, of caloric free to move by radiation, being permanently attached in the form of an atmosphere around the earth, as well as intermixed with the aerial atmosphere, in opposition to its inherent repulsive tendency to diffuse itself equally throughout unoccupied space, I am inclined to think, that the amount of caloric in a given space, including both what is latent and sensible, must increase in a somewhat less ratio towards the earth's centre, than the amount of ponderable matter by which it is attracted.

But, then, as attractive or repulsive forces exerted by matter, are inherent in, and inseparable from, the matter itself; it follows, that in proportion as the absolute amount of caloric, relative to that of ponderable matter, is diminished by condensation towards the centre of the earth; so should its central portions be exerting a stronger degree of under-saturated attraction upon all surrounding caloric. Consequently, it may be inferred, that this unsatisfied, though distant attraction for caloric, which is exerted in the strongest degree by the central and densest portions of the earth, must have an influence in concentrating and retaining a calorific atmosphere around its surface; and in increasing the amount of caloric intermixed with the aerial atmosphere, and with the superficial and less condensed strata immediately subjacent, beyond what their own unassisted attraction for it would be able to concentrate, and hold in affinity.

Finally, judging from the facility with which caloric pervades all ponderable materials, and which enables it to adjust itself in obedience to the forces by which it is actuated; it may be inferred, (except for accidental causes, and periodic variations, the latter of which is in a great measure restricted to the atmosphere, and to within 40 feet of descent below the surface of the ground,) that in each concentric layer of the earth, other things equal, the quantity of caloric distributed continues always the same. And though the quantity of caloric contained in a given space, and the temperature, as indicated by thermometers, may increase within, and possibly far beyond attainable depths, in descending from the earth's surface towards its centre; still, we believe that the quantity distributed in each concentric layer, under an equal superincumbent pressure, (if other circumstances be alike,) is constantly the same; and is, and has always been, proportional to the degree of influence exerted upon caloric by the unaltered, and unvarying conjoint forces, of attraction for ponderable materials, and repulsion subsisting between its own particles, modified by the compression of external strata of ponderable materials gravitating towards the earth's centre.

In accordance with the preceding observations, we believe that the interior parts of the earth, as tested by thermometers, are warmer than those that are exterior; and that the temperature increases with the depth below the surface. But as we farther believe that this is the natural and permanent distribution of caloric, resulting from the conjoint influence of the forces which permanently act upon it, at different depths, with different degrees of strength; we disbelieve in the doctrine, at present universally received by the advocates for the hypothesis of the earth's central heat, that the globe is gradually undergoing a reduction of temperature, in consequence of that central heat slowly penetrating its crust, and escaping for ever into celestial space, by radiation from its surface.

On the Distribution of Caloric throughout the Celestial Spaces.—The preceding observations relative to the distribution of caloric attached to the earth, are equally applicable, and may be extended by analogy, to all other celestial orbs. And as the different spheres of the universe differ greatly in size, its distribution, so far as it is thereupon dependent, must be subject to corresponding modifications. For instance, it has been estimated that the sun contains about 600 times more matter than all the planets put together. Consequently, its central portions must be immensely more compressed, and correspondingly more deprived of caloric, relative to the amount of ponderable matter in a given space, by the weight of superincumbent strata, than the central portions of the earth are. It may, therefore, be inferred, that the unneutralized attraction for caloric, which these highly condensed central masses exert towards it, must cause the calorific atmosphere surrounding the sun, not only to be greatly denser, but also to extend to a much farther distance around its surface, than that which encompasses the earth.

On receding exteriorly from the surface of the earth, and from that of other celestial orbs, the quantity of caloric in a given space must gradually diminish. But whether it is wholly concentrated around and within limited distances from the surface of celestial bodies, so as to leave an entire vacuity between them; or whether it extends from sphere to sphere, and from system to system, must depend upon what we have no certain means of determining, viz. the amount of caloric in existence. We will here present two views of the distribution of caloric, throughout the celestial spaces of the universe, accommodated to this unascertained difference in the existing amounts of caloric; and will assign the reason why we have given a preference to the former of these, as being the more probable.

1*st View.*—If the attraction exerted upon caloric by the several revolving orbs of ponderable matter, be sufficient to counteract the mutual repulsion subsisting between the whole calorific particles that exist, so as to cause their concentration around them, within moderate distances of their respective surfaces; then the amount of caloric, in a given space, attached to each sphere, should gradually diminish on receding externally from its surface, till its external boundary be attained. At what distance from the earth's surface this boundary may be, must for ever remain unknown; though it is probably considerably beyond that of the atmosphere.

According to this view of the distribution of caloric, each planetary body permanently consists of the same ponderable matter, and the same caloric, and probably also, of the same imponderable materials of all kinds. It supposes that an entire vacuity between one planetary body and another exists; and that suns, stars, planets, satellites, and comets, revolve in their respective orbits, without being obstructed by the presence of any material substance. It also supposes, that the changes of temperature which we experience, during day and night, and the different seasons of the year, are not produced by the transmission of caloric, or other imponderable matter, from the sun to the earth, or from one planetary body to another; but consist merely of periodic alterations, in the distribution, over the earth's surface, of the same identical amount of caloric, which is permanently and inseparably attached to the globe, throughout all its revolutions.

2d View.—If the sun, and planetary bodies, be unable, by the force of attraction, to concentrate the whole caloric belonging to the system, within moderate distances of their respective surfaces, so as to leave intermediate spaces, between one planetary body and another, entirely void of caloric, and other imponderable matter; then caloric may be conceived as extending to the farthest boundaries of the system, without any vacuity. In this case, the sun may be regarded not only as the great centre of ponderable matter, but the great nucleus, within and around the surface of which, caloric and the other imponderable bodies, whose particles repel each other, are concentrated by attraction, in infinitely greatest quantity and density. And as the sun contains above 600 times more ponderable matter than all the planets put together, the calorific atmosphere by which it is surrounded, may be supposed to extend to the circumference of the solar system, gradually becoming more rarefied, like an atmosphere, as it approaches that limit. And the different planets, satellites, and comets, may be regarded as comparatively extremely small revolving nuclei of attraction, around and within which, caloric and the other imponderable bodies, are also concentrated, in proportionally smaller quantities, and in similar distribution and arrangement.

Agreeably to this view of the material system, planetary bodies in their orbits, may be conceived to pervade an extremely rare atmosphere of caloric, retained in attraction by the sun, which diminishes in density as the distance from that luminary increases. Consequently, comets, in their approach from their aphelion towards the sun, are progressively getting immersed in a denser calorific atmosphere. And like bodies around us slowly introduced into a warmer temperature, they must gradually become heated, by absorbing caloric in proportion to their attraction for it, modified by the quantity in a given space, by which, in different parts of their orbits, they are immediately surrounded. And according to the same principle inverted, comets must gradually part with caloric, in proportion as the calorific atmosphere which they traverse, on receding from the sun, becomes rarefied.

The centrifugal velocity of planetary bodies, agreeably to this second view of the distribution of caloric, admits of explanation, upon principles strictly analogous (and which need not be repeated) to those according to which they have been accounted for, in the preceding half of this volume, in conformity with the first view. Different portions of the spherical surface of planetary bodies during rotation, may be conceived as absorbing caloric during day, with greater or less rapidity, according as they are more directly presented to the sun, and the warmest portion of the heavens; and again giving it out during night, when they are turned away from that luminary, and directed towards a colder quarter of the heavens.

This second view of the distribution of caloric has the advantage of the first, in affording a means of explaining how the different systems of the universe can have no tendency to approximate, but may remain for ever separate at their present distances, without the aid of any revolutionary movements round each other. If the attractive forces exerted by the sun, and the other planetary bodies of the solar system, towards the different stars of the universe, be stronger than the repellent force; it is obvious, that unless the excess of attraction be balanced by the centrifugal velocity of revolving round each other, they must gradually and ultimately concentrate. But if this second view of the material system be correct, the different systems of the universe may have no tendency to concentrate, even though they perform no revolutionary movements round each other. Though the attractive forces mutually subsisting between the sun and the different planetary bodies of our system, may preponderate over the repulsive; still, if the repellent force of all that extremely rarefied calorific atmosphere, which this second view of the material system supposes to extend to, and perhaps beyond, the boundaries of the solar system, be added to the repulsion exerted by the repellent materials contained in all the planetary bodies of the system; the aggregate repulsive force may be an exact counterpoise to the aggregate attractive force, exerted by the ponderable and imponderable materials composing the solar system, towards the ponderable and imponderable materials of all other systems.

Agreeably to this view, it might even be supposed that the calorific atmosphere, in a still more rarefied form, extended, without any intermediate vacuity, from one planetary system to another. But as its attraction for ponderable matter, in such intermediate situations, would be counterbalanced, and neutralized, by the repulsion exerted by caloric, and other imponderable materials contained in each system ; its distribution, in such intermediate situations, would be effected solely by repulsion subsisting between its own particles.

This second view of the distribution of caloric throughout the material system, was that which first suggested itself to my mind, and is the one I was first inclined to espouse, in order to account for centrifugal velocity in planetary motion. Upon subsequent consideration, however, I have been led to prefer the first view; and accordingly have adopted it in the previous treatise on centrifugal force, chiefly for the reason mentioned in our observations on a supposed resisting medium. The reason alluded to is, that if caloric, or light, exist in a state of diffusion throughout the celestial spaces in which planetary bodies revolve, the side of the earth which proceeds foremost in the orbit, in consequence of pressing against the calorific or luminiferous particles diffused throughout space, with the velocity of 68,080 miles an hour, should be the warmest, and the most enlightened, whereas, it is always the coldest, and light is then just beginning to dawn.

We have evidence of the orbitual revolutions of what have been called Binary stars; and the principles according to which they must be performed, agreeably to our theory, are analogous to those according to which bodies belonging to the same system have been accounted for. But, with the exception of Binary stars, and some very imperfect evidence that the solar system is advancing in the direction of the constellation Hercules, we are totally ignorant whether or not revolutions are performed by the fixed stars round each other, or round a common centre of gravity. Without such knowledge, it is perhaps unphilosophical to speculate farther on the subject. Nevertheless, it may be conjectured, that the different systems of the universe have probably no more tendency to approximate, so as ultimately to destroy each other, than the different planetary bodies of the solar system. At present, however, we have not a sufficiency of facts or information, to enable us to form an opinion as to how their separation is permanently maintained.

SECTION XXXVI.

ON THE DECREASE IN THE ATMOSPHERIC TEMPERATURE ON ASCENDING PERPENDICULARLY.

In the first part of the preceding Section, we endeavoured to show, that, in descending from the surface to the centre of a sphere composed of ponderable and imponderable materials, such as the earth, the amount of ponderable matter, in a given space, was increased by the condensation effected, by the progressive augmentation in the superincumbent weight of external strata. And from taking a survey of the conjoint influence of the forces, which must determine the relative amounts of caloric in a given space, in every concentric layer of ponderable matter; we endeavoured likewise to show, that the amount of caloric in a given space, from the surface towards the centre of the earth, must also be gradually augmented, though in a somewhat less ratio, (the degree less being unknown,) than that in which the amount of ponderable matter in a given space is increased.

On this subject, the limits of actual observation have been hitherto restricted to about 20,000 feet of atmosphere above the level of the sea, and to something less than 2000 feet of perpendicular descent below the surface of the ground. Beyond these limits our knowledge, relative to the distribution of caloric, and of temperature, by which that distribution is estimated, consists merely of inferences, deduced from what is observed to take place within the boundaries of actual observation.

In this Section we purpose to restrict our inquiry to the consideration of the decrease in the atmospheric temperature, upon ascending perpendicularly, the nature and cause of which is, in my opinion, only partially understood; and it is even questionable, as we will see by and bye, whether it can be said to be understood at all. And in the next Section, we will enter upon the investigation of the increase of temperature, on descending perpendicularly below the surface of the ground, the nature and cause of which still remains a mystery, and even the facts of the case are considered by many as requiring re-examination.

It has been ascertained that the temperature of the atmosphere, in all latitudes, diminishes on ascending perpendicularly from the level of the sea, to all attainable altitudes; but the rate of diminution, as determined by different, and even by the same observers, at different times and places, varies greatly. It appears, also, that the rate of diminution is, in general, more rapid in summer than in winter; and from recent researches there is reason to believe, that the ratio of decrease usually becomes somewhat slower, but not very considerably, as we ascend. Thus, upon the supposition that the first 252 feet of ascent reduces the temperature one degree of Fahrenheit, the second degree of reduction will require an additional ascent of 255 feet; the third degree, an additional ascent of 258 feet, and so on. From the various results obtained by different observers at different times and places, and partly, perhaps, with a view to facilitate calculation, meteorologists, in general references to this point, have adopted one degree of Fahrenheit as the mean rate of decrement for every 300 feet of perpendicular ascent, within attainable altitudes.

In explanation of the fact under consideration, Dr. Dalton, and afterwards Sir John Leslie, endeavoured to demonstrate, that heat exists in a state of equilibrium in the atmosphere, when each of the atmospheric molecules, or in other words, when the same weight of air, in every part of the same atmospheric column, contains the same quantity of heat. And as the capacity of air for caloric is supposed to increase, upon ascending perpendicularly, exactly in proportion as the superincumbent atmospheric pressure diminishes; the temperature of the air is reduced on ascending, in the same ratio as its latent heat is augmented.

The preceding explanation, which is now universally received, only accounts for the phenomena, as we shall see by and bye, in a defective, if we may not say, an erroneous manner. It may be questioned, for instance, whether the equilibrium of heat in the atmospheric columns requires that each atmospheric molecule, or, in other words, that the same weight of air, in every part of the same perpendicular column, should contain the same amount of heat. If this be the case, atmospheric compression, though it diminishes the specific heat of air, has no influence in diminishing the absolute amount of heat which a given weight of it contains. And of course, the amount of caloric, including both what is latent and sensible, must increase in a given space, from the summit to the base of the atmosphere, not in a somewhat less ratio, (the extent less not being known, as we have supposed in the previous Section,) but in exactly the same proportion as the amount of ponderable matter, which attracts it, is augmented. We know that the specific heat of air, as well as the absolute amount of caloric contained in a given weight of it, are diminished, with only a temporary augmentation of temperature, in all cases of artificial condensation. But we also know, that though the specific heat of a given weight of air be as much diminished by atmospheric, as it is by a like extent of artificial pressure; still, from the permanent increase of temperature which is observed in descending through the atmosphere, it is evident, that the absolute amount of heat in a given weight of air, is not diminished to the same extent, (if it be diminished at all,) by the former, as it is by the latter. There must, therefore, be some compensating cause, which in some degree, less or more, prevents the absolute amount of caloric contained in the atmosphere from being diminished by incumbent atmospheric pressure, in the same ratio as it is diminished by artificial compression.

On the other hand, amidst so many causes of variation in the temperature of the atmospheric columns at different heights, it is impossible to determine the actual mean rate, in which the atmospheric temperature sinks on ascending perpendicularly; and it is likewise impossible to determine the actual absolute amount of caloric contained in a given weight, either of air, or of any other substance. Hence, therefore, though it were experimentally ascertained, that as the volume of air increases, its specific heat augments in the same proportion, (and the experiments and calculations made to determine this point, are mixed up with inferences that are mere conjectures;) still, for want of the knowledge above stated, and likewise from being unacquainted with the extent of influence exerted by the compensating cause, alluded to at the end of the preceding paragraph, and to which, in this Section, we will again have occasion to refer, it is in vain to think of demonstrating, with perfect certainty and precision, as has been attempted, that the equilibrium of heat in the atmosphere surrounding the globe, occurs when each atmospheric molecule, or when the same weight of air, in every part of the same perpendicular column, contains the same quantity of heat. Provided the upper molecules of air severally contained a smaller proportion of caloric than those underneath, it is obvious that those above would be specifically heaviest, and accordingly would sink down and displace those underneath. But it is also obvious, that the upper and lower atmospheric molecules can have no tendency to change places, whether the upper ones contain the same, or any greater amount of caloric, than those below.

From the following experiment it appears, that the distribution of caloric throughout the atmosphere, depends upon the conjoint influence of all the forces acting upon caloric stated in the previous Section, and not exclusively upon the attraction, or affinity, exerted towards it by the individual molecules.

If a thermometer be suspended in the exhausted receiver of an air-pump, or in a Torricellian vacuum, it stands at the same degree of temperature as one suspended externally in the unrarefied atmosphere; and variations of temperature affect both thermometers in the same manner, and ultimately in the same degree. It is true, that upon exhausting the air suddenly by means of an air-pump, a delicate thermometer suspended in the receiver sinks; but then it very soon regains its former temperature without any re-admission of air. In like manner, after the thermometer within the exhausted receiver has acquired the same temperature as the one outside, the sudden re-admission of air into the receiver, instantaneously causes the thermometer within the receiver, to rise in temperature above the one suspended externally. But, as in the other case, the temperature of the former very soon thereafter sinks, till it regains an equality with the latter.

The preceding experiment, considered in conjunction with the fact of the aerial temperature always sinking upon ascending perpendicularly, leads to a variety of conclusions. In the first place, it indicates that only a portion of the caloric contained in the atmosphere, is attached by affinity to the ponderable bases of the aerial molecules; and consequently, that the permanent reduction of temperature, on ascending in the atmosphere, is not owing exclusively to the increased calorific capacity of the individual molecules of air, when their density, as the force by which they are compressed, is diminished, as the explanation of

Dr. Dalton and Sir John Leslie, would lead us to suppose. If such were the case, an equally permanent reduction of temperature, should be exhibited by a thermometer in a proportionally exhausted receiver. Provided the whole caloric contained in the atmosphere were held in affinity by, and divided amongst, the individual molecules of air, a thermometer suspended in a receiver exhausted, or nearly exhausted of air, by an air-pump, ought to exhibit the same temperature, as a thermometer would do at an elevation in the atmosphere, where the air was equally rarefied with that in the exhausted receiver. But this is not the case. On the contrary, the thermometer within the exhausted receiver exhibits exactly the same temperature, and the same variations of temperature, as the one in the external unrarefied air by which it is immediately surrounded. This fact demonstrates, that caloric, without the re-admission of air, passes readily through the glass receiver, and distributes itself within it, altogether independent of the assistance of any union with aerial molecules. On the other hand, the fact of the temperature instantly sinking within the receiver, upon the sudden withdrawal of air, demonstrates, that a portion of caloric contained in the atmosphere, is actually attached by attraction or affinity, to the ponderable bases of the individual molecules of air, and is withdrawn by means of the air-pump, along with them. From these facts, we arrive at the same conclusion, as we previously came to, upon considering the phenomena of combustion, viz. that one portion of caloric contained in the atmosphere, is attached by affinity to the individual molecules of air; while another portion exists intermediate between the aerial particles, without being attached to them by affinity; that the former portion always moves along with the aerial particles to which it is attached; while the latter, which is the only portion that radiates, is free to move by radiation, in obedience to the preponderance of forces acting upon it.

In the second place, the preceding experiment, considered in conjunction with the fact, of the aerial temperature always sinking upon ascending perpendicularly, shows that inequality of temperature, as indicated by a thermometer, does not invariably denote a disturbance of the calorific equilibrium, and that a movement of caloric from the bodies or spaces, where temperature is highest, to where it is lowest, must be thereby produced. If inequality of temperature invariably indicated such a movement, caloric would continue to rise from the lower to the higher aerial strata, till the atmosphere exhibited the same temperature from its base to its summit. But the circumstance of the decrease in the atmospheric temperature upon ascending, being permanent, demonstrates, that caloric has no such ascending tendency, so long as the natural ratio of decrease that constitutes the equilibrium of caloric in the atmosphere, which, on an average, appears to be about 1 degree of Fahrenheit, for every 300 feet of perpendicular ascent, is not exceeded.

The reason usually assigned for caloric having no tendency to rise from the base of the atmosphere, in order to restore equality of temperature in all the aerial strata, is, agreeably to the theory of Dalton and Leslie, that each of the atmospheric molecules, or in other words, that the same weight of air, in every part of the same perpendicular column, retains in affinity the same quantity of heat, including both what is latent and sensible. Now, the preceding experiment proves that this explanation is not strictly correct. The temperature of a partially exhausted receiver, as indicated by a thermometer suspended inside, is the same as that of the external unrarefied air by which it is immediately surrounded. If we transfer the exhausted receiver from the level of the sea to the height of 3000 feet, its temperature sinks 10 degrees, because the temperature of the air by which it is immediately surrounded at that elevation, is 10 degrees lower than at the level of the sea. But though the temperature of the partially exhausted receiver sinks 10 degrees, by being transported from the level of the sea to the elevation of 3000 feet; still, the number of atmospheric molecules, or in other words, the weight of air within the receiver, is not thereby in the least diminished. Hence the theory of Dalton and Leslie, that the equilibrium of heat in the atmosphere, depends upon each of the atmospheric molecules, or in other words, upon the same weight of air, in every part of the same atmospheric column, containing the same quantity of heat, fails in affording an explanation of the phenomenon, and therefore cannot be correct.

As the amount of ponderable particles in a given space increases in descending from the summit to the base of the atmosphere, so the absolute amount of attractive force exerted in a given space by these ponderable particles towards caloric, is also proportionally increased. But we will endeavour to show in Section XXXVIII. that, when a body composed of ponderable matter and caloric is condensed by compression, the repulsion subsisting between the particles of caloric is increased in a more rapid ratio, than the attraction exerted towards them by the condensed ponderable matter; and that the diminution in the specific heat of bodies, upon being condensed, results from this circumstance. Now, as the incumbent atmospheric pressure diminishes upon ascending perpendicularly, the distribution of caloric in the different concentric layers of atmosphere, is determined, not merely by the number of aerial particles which attract it, but also by the mutual repulsion subsisting between its own particles. Consequently, the equilibrium of caloric requires, that its distribution in a given space, should be proportioned to the attractive force exerted in that space by ponderable matter towards it; and likewise, that the mutual repulsion subsisting between the particles of caloric in all contiguous spaces, whether containing ponderable matter or not, should be in a state of equal tension.

Now, equality of temperature among contiguous bodies, and spaces whether containing ponderable matter or not, is the consequence, and indication, of caloric being distributed amongst them in a state of equilibrium, or equal tension; and inequality of temperature is the consequence, and indication, of a distribution of caloric different from that in which its equilibrium, or state of equal tension consists. If the vacuum in the receiver of an air-pump be reduced in temperature below that of the surrounding air, caloric passes into it from the surrounding air, not in consequence of being attracted by any ponderable matter therein, (for it is comparatively void of ponderable matter,) but in consequence of the repulsive force exerted by caloric within the exhausted receiver, not being sufficiently strong to balance the repulsive force exerted towards it, by caloric in the surrounding air.

By way of illustrating the subject under consideration, we may here suppose a case, and describe, and endeavour to explain, the phenomena presented, in the order of cause and effect. Supposing we descend 3000 feet from the summit towards the base of the atmosphere, the effects produced are as follows:—1*st*. The incumbent weight of atmosphere is augmented. 2*d*. This augmentation in the incumbent weight of atmosphere, increases the number of the ponderable particles of air in a given space, and of course increases in an equal degree the attractive force which they exert towards caloric in that space. 3*d*. As all the vacuities in any body, composed of ponderable and imponderable materials, subsist between the particles of caloric that surround and separate the ponderable particles, condensation of any such body diminishes the space throughout which the caloric contained in it is diffused, in a greater ratio than it diminishes the aggregate bulk of the whole body. The consequence is, that the repulsive force subsisting between the particles of caloric contained in any body is increased, during its condensation, in a greater degree than the attractive force exerted by the approximated ponderable particles towards caloric. Owing to this circumstance, condensation of bodies operates like increasing the repellent force mutually subsisting between calorific particles; and hence the reason why it diminishes the specific heat of bodies. *4th.* This increased repellent force subsisting between the particles of caloric, requires to be balanced by a correspondingly augmented calorific repellent force in all contiguous bodies or spaces; otherwise, caloric must pass into them from the condensed body, or in the case under consideration, from the compressed aerial strata. Hence the reason that mercury in a thermometer, and also the space within an exhausted receiver, and water, or any other substance, if carried instantaneously 3000 feet downwards through the atmosphere, must continue to receive caloric, till the amount they contain, acting as a counterpoise to the increased repulsion, (arising from compression,) of that by which they are surrounded, restores the calorific equilibrium; and this takes place when the temperature of the translated bodies has risen 10 degrees, which brings it to equality with that of the immediately surrounding air, and all other substances at the same elevation. Suppose another descent of 3000 feet is made, a similar augmentation of atmospheric compression, and a like increase in the amount of ponderable matter, and of caloric in a given space, takes place; and a corresponding augmentation in the repellent force subsisting between the particles of caloric, which, in order to the equilibrium of heat, and equality of temperature among contiguous bodies, requires to be balanced by a like increase in the amount of calorific repulsion among surrounding bodies. Of course, the temperature of the thermometer, and the exhausted receiver, &c. upon being transferred downwards this second 3000 feet, again rises 10 degrees by imbibing caloric from contiguous bodies; and so on of every farther descent.

The diminished specific heat of the strata of air in descending, results not, strictly speaking, from increase in their density, but from the augmentation in the incumbent atmospheric pressure. The diminution in the specific heat of air on descending, is merely a concomitant effect of the increase in its density; and both arise from the same cause, viz. an augmentation of incumbent atmospheric pressure.

We now come to the last and most difficult point of the inquiry, regarding the nature and cause of which, the explanations of Dalton, and Sir John

Leslie, if strictly examined, give no information. The point alluded to is, how inequality of temperature, amounting to an increment of one degree of Fahrenheit, for every 300 feet of descent in the atmosphere, should produce no disturbance of the calorific equilibrium, so as to cause a movement of caloric from where temperature, as indicated by a thermometer, is highest, to where it is lowest. Such an inequality of temperature in the atmosphere horizontally, always produces a calorific movement, till equality of temperature, as indicated by thermometers, is restored. How is this effect not produced perpendicularly in the atmosphere, in the same manner as it is produced horizontally? How does not a portion of the caloric contained in the warm strata at the base of the atmosphere, pass upwards to the colder atmospheric strata above? Before attempting to answer these queries, (and we can only do so hypothetically,) we will briefly restate what the phenomenon under consideration cannot be owing to.

1*st.* From the circumstance of a thermometer in an exhausted receiver, exhibiting the same temperature, and the same variations of temperature, at all altitudes, as one suspended externally in the unrarefied air immediately surrounding the receiver, we demonstrated, that the phenomenon under consideration, does not result from each of the atmospheric molecules, or in other words, from the same weight of air in every part of the same perpendicular column, having attached to it by affinity the same quantity of heat, including both what is latent and sensible, as the theory of Dalton and Leslie would lead us to suppose.

2*d*. The phenomenon under consideration, strictly speaking, is not owing to diminution in the specific heat of the atmosphere, and to a proportion of the heat becoming sensible as the incumbent atmospheric pressure increases, which, but for the additional pressure on descending, would remain latent. This will be evident upon considering the following remarks. If we condense any portion of air artificially, by means of a condenser, a portion of its caloric is instantly converted from latent to sensible heat; but in this altered state it is not permanently retained in the condensed air. No; it is expelled altogether, and the direction which it principally takes upon being expelled, is the coldest direction, and where it meets with least obstruction in its passage, whether upwards, downwards, or in any other way; and farther, the expelled caloric does not return into the condensed air, so long as it remains condensed. Now, supposing an additional amount of air supervenes any country, such as is indicated by an unusual rise in the barometer, amounting to three inches. The specific heat of the lower strata of air, in that case, is reduced as much as it would be by artificial pressure, equal in weight to a column of three inches of mercury. How does it happen that the pressure arising from the supervention of additional atmosphere, produces a permanent augmentation of temperature in the lower aerial strata, by converting a portion of their latent heat into sensible heat; while an equal degree of artificial pressure upon air, expels a portion of its caloric altogether, and does not raise the temperature of the condensed air permanently, in any degree whatever? To say, with Dr. Dalton and Sir John Leslie, that the permanent increase in the aerial temperature on descending, arises from the augmentation in the aerial compression producing a diminution in the specific heat of the atmosphere, which converts a portion of its latent heat into sensible heat, is merely a general description of the phenomena, and not an explanation of them. It evades all attempt to account for the difficulty under consideration, while, at first sight, it has the appearance of accounting for it.

The conversion of the latent heat of the atmosphere into sensible heat, and, especially, the permanent retention of the converted heat, so as to cause an augmenting temperature, as the incumbent pressure, upon descending through the atmosphere, becomes greater, demonstrates, that the effect is produced by some permanent cause, which does not exist in cases of artificial condensation. Now, I conceive that the effect under consideration is produced, by the repulsion exerted by caloric contained in the superior atmospheric strata, towards caloric contained in the inferior strata. In fact, the repulsion of external towards interior caloric, operates, as it were, by compression, like the superincumbent weight of external strata of ponderable materials, towards similar materials that are interior to them. As we descend in the atmosphere, the greater is the amount of external caloric repelling that which is within; and, consequently, the greater is the calorific compression exerted upon it. And if a portion of caloric in the higher strata of the atmosphere be withdrawn, a portion of the calorific compression is removed, and caloric tends to rise up from the lower strata. Such I conceive to be the reason why a portion of the caloric in the atmosphere, upon being converted from latent into sensible heat, is permanently retained.

By reflecting on the following circumstances, the truth of the preceding hypothetical explanation appears to be strikingly confirmed. In all cases of artificial condensation of air, the cause of condensation produces no corresponding increase of calorific repulsion, above and around the portion of air that is condensed. And, consequently, the latent heat artificially converted by condensation into sensible heat, escapes by dispersion, and cannot be retained in the condensed air. But when condensation is produced by the supervention of an additional amount of atmosphere, as we descend perpendicularly, the cause of condensation is uniformly attended by a corresponding augmentation of incumbent caloric, which, by repelling all caloric interior to it, in part compensates (so far, at least, as retention of heat is concerned) for the diminution in the specific heat of the air caused by increased atmospheric compression. And this compensating circumstance, I conceive, has the effect of retaining the latent heat of the inferior aerial strata, even though converted by compression into sensible heat, when the amount so converted, does not elevate the atmospheric temperature on descending perpendicularly above the mean rate of one degree for every 300 feet.

If it be said, by way of objection to the preceding explanation, that the increase in the amount of external caloric on descending, is also attended by a corresponding increase of ponderable matter ; and that the attraction exerted towards interior caloric by the superior ponderable matter, should balance the repulsion of the external caloric towards that which is interior. To this objection it may be answered, that we have no means of estimating the relative influence of forces but by their effects. And judging from the permanent increase of temperature as we descend in the atmosphere, without being able to account for it otherwise than we have done, I conceive that the one is not a sufficient counterpoise to the other.

Thus we see, that though what is called inequality of temperature, in the same concentric layer of atmosphere, or of other terrestrial materials, invariably indicates a disturbance of the calorific equilibrium, which produces a movement of caloric from where temperature, as indicated by a thermometer, is highest, to where it is lowest; still, such is not true in regard to the successive concentric layers, either of atmosphere, or as we shall see by and bye, of denser ponderable matter, more and more compressed by the increasing weight of superincumbent strata, as we descend from the surface to the centre of a globe, or sphere, such as the earth. On the contrary, the circumstance of the decrease in the aerial temperature, upon ascending, being permanent, demonstrates, that the equilibrium of heat in the atmosphere occurs, when the temperature sinks, at the mean rate of one degree of Fahrenheit, for every 300 feet of perpendicular ascent. And so long as the ratio of decrement is neither less nor greater than this, caloric remains in a state of equilibrium, and has no tendency either to sink or rise in the atmosphere. In like manner, there is reason to believe, as we shall endeavour to show in the next Section, that the permanent increase in the temperature of the earth, below the depth of 40 feet, at the mean rate of one degree for every 50 feet of perpendicular descent, is also that which constitutes the equilibrium of heat. And that so long as this ratio of increment upon descending is preserved, caloric has no tendency to penetrate the terrestrial strata of ponderable materials, either towards, or from the earth's centre.

SECTION XXXVII.

NEW VIEWS REGARDING THE NATURE AND CAUSE OF THE INCREASE OF TEMPERATURE, ON DESCENDING PERPENDICULARLY BELOW THE SURFACE OF THE GROUND.

In digging down below the surface of the ground, the maximum temperature of summer, and the minimum of winter, are longer after the summer and winter solstices of being attained; and the annual range of temperature gradually becomes less. According to the observations of Mr. Ferguson of Raith, in his garden at Abbotshall, about 50 feet above the level of the sea, and nearly a mile from the shore of Kirkaldy, in N. Lat. 56° 10′, a thermometer imbedded in the earth at a depth of one foot below the surface, reached its maximum and minimum temperatures, about three weeks after the summer and winter solstices: its extreme range being 25°. A thermometer at the depth of two feet, reached its maximum and minimum temperatures, about four or five weeks after the solstices: its range being 20°. Another thermometer at the depth of four feet, did not reach its maximum and minimum temperatures, till nearly two months after the solstices: its range being only 15°. And a thermometer at the depth of eight feet, did not reach its maximum and minimum temperatures, till nearly three months after the solstices of summer and winter: and its range was only 9½°. These facts show the slowness with which increased temperature penetrates the earth by conduction, a fact to which we shall subsequently have occasion to refer.

In descending below the limits above-mentioned, the annual range of temperature gradually gets less, till it becomes altogether imperceptible. The depth at which this occurs, varies in different places, even when the influence of the external air is excluded, (and this can only be done to a moderate depth,) from about 25 to 55 feet. Such variations depend partly upon the extent of the annual range of temperature at the surface of the ground; and partly upon the difference in the power of terrestrial materials, at and near the surface, in conducting caloric. Of course, the greater the annual range of temperature at the place of observation is, and the better fitted the materials, at and near the surface of the ground, are for conducting caloric, the deeper should the annual variations of temperature be felt. Somewhere about 40 feet may be taken as the mean depth, at which the temperature first remains unaltered throughout the year. And the temperature of the earth at that depth, and of water coming from that depth, may be considered as representing the mean annual atmospheric temperature of the place, at the surface of the ground.

Below the depth at which the temperature remains unaltered throughout the year, the tempeture, as ascertained in a great variety of mines in different quarters of the world, always increases with the depth; the rapidity of increase being very different in different mines, but which, when averaged, gives a mean of about 1° of Fahrenheit for every 50 feet of perpendicular descent. And it deserves to be particularly remarked, that the ratio of increment with the depth, is similar in all latitudes, and does not seem to be in the least dependent upon whether the mine be sunk in a low-lying, or in an elevated country. At about 40 feet below the surface, the mean annual atmospheric temperature at the mouth of the mine is attained, whether it be at the level of the sea, or any height above it; and the temperature rises at the mean rate of one degree for every 50 feet of farther descent. In the mass of experiments, the temperature of air, or of water, at different depths, has been taken, as indicating the temperature of the earth at these depths; and comparatively few observations have been made by imbedding thermometers in the earth itself, which would have been a much better mode of experimenting, in order to ascertain the actual rate at which the temperature increases on descending perpendicularly.

Dr. Thomson, in his work entitled "Outlines of Mineralogy, Geology, and Mineral Analysis," after giving a detailed account of the observations that have been made upon this subject, gives the following abstract of them, preceded and followed by the subjoined remarks.

"The preceding Tables contain all the observations on the temperature of mines hitherto published, or at least which have come to my knowledge. With a few insignificant objections, which can be easily accounted for, they show that the temperature rises as we sink deeper into the earth. But there is a very great difference in the rate of this increase in different mines. It may be worth while to collect this rate, as deduced from the different mines observed.

	Degree Fah.		Feet.
1. Huel Abraham,	1	for	43
2. United Mines,	1	—	64
3. Dolcoath,	1	—	77
4. Turcroft,	1	—	66⅔
5. Cook's Kitchen,	1	—	50
6. Whitehaven,	1	—	43
7. Workington,	1	—	42
8. Teen,	1	—	37
9. Percy Main,	1	—	47
10. Jarrow,	1	—	46
11. Killingworth,	1	—	48
12. Beschertgluch,	1	—	38·5
13. Hoffnung-Gottes,	1	—	57
14. Poullaouen,	1	—	157
15. Huel Goat,	1	—	48
16. Carmeaux,	1	—	50
17. Littry,	1	—	36
18. Decises,	1	—	30
19. Herzogenrath,	1	—	76
20. Bagoslowsk,	1	—	34
21. Charlieshope,	1	—	22

“ The difference is enormous. In the mine of Decises there is an elevation of 1° for every 30 feet of descent; while in Poullaouen, an elevation of 1° requires a descent of 157 feet, or more than five times as great. If we were to leave out Poullaouen and Charlieshope, as deviating too much from the rest, and take the mean of all the others, we would obtain nearly an increase of 1° for every 50 feet of descent."

Of these facts various explanations have been given. By some the augmentation of temperature has been ascribed to accidental causes, such as the burning of candles, blasting of gunpowder, and the heat emanating from the bodies of the workmen employed in the mines. This explanation has been refuted by calculations made by Dr. Forbes, to determine the amount of heat which could arise from these causes, in the mine of Dolcoath, and compared with the amount of heat abstracted from the mine, by the heated water pumped out of it daily. The result of his calculations showed that the whole heat produced by all the adventitious causes put together, did not amount to $\frac{1}{15}$th of the heat which the water pumped out of the mine, contained above the mean annual atmospheric temperature at the mouth of the mine.

At the meeting of the British Association at Liverpool, in 1837, Mr. Fox stated the result of a number of observations made by him in various mines, with a view to determine how far the increased temperature, on descending, depended upon adventitious circumstances. His plan of procedure, so far as I could hear his verbal statement of it, was by comparing the temperature indicated by two thermometers, one of which he imbedded in the earth three feet deep, at the bottom of the mine, and the other he imbedded only perhaps one foot in the earth, or in other cases merely placed it on the ground at the bottom of the mine, without being imbedded at all. In all his experiments he uniformly found that the imbedded thermometer, or the one that was deepest imbedded, indicated a higher temperature than the other, the difference between them varying in different experiments from one to four degrees. From the results obtained by Mr. Fox, it is obvious, that the temperature in mines, instead of being augmented, is actually reduced, by the aggregate operations carried on in them. And, consequently, it may be inferred, that the temperature of the earth, upon descending perpendicularly, increases more rapidly than the observations made in mines have indicated.

The explanation of the increase of temperature upon descending into the earth, which is at present almost universally adopted, is, that the central parts of the globe are in a state of intense ignition, and that the temperature gradually diminishes as we approach its surface. The interior central heat is supposed to be slowly penetrating the crust of the earth, and diffusing itself into celestial space, by radiation from its surface. According to this theory, the globe, considered as a whole, is undergoing a slow cooling process; and the temperature of its surface is maintained, partly by the dissipation of this central heat, and partly by the heat of the sun. In the torrid zone, it is conceived that the waste of the earth's central heat by diffusion, is replaced by the heat of the sun. But in temperate and high latitudes, owing to the obliquity of the solar rays, it is supposed that the temperature of the earth's surface has been gradually, and permanently sinking, for an indefinite length of time; and that it still continues to sink, in consequence of the waste of the central heat of the earth, by diffusion into celestial space, being greater, than the supply received from the sun.

The preceding explanation, if we except the fact itself, viz. the augmentation in the earth's temperature upon descending perpendicularly, I conceive to be totally erroneous. That the temperature of the earth actually does increase on penetrating perpendicularly, I believe on the evidence of the facts adduced in proof thereof, an abstract of which we quoted from Dr. Thomson's work on Geology. But that the globe at present contains an immense excess of caloric beyond what it can retain in affinity; and, accordingly, that it is undergoing a gradual cooling process, in consequence of this central heat slowly penetrating its crust, and escaping for ever by radiation from its surface, I disbelieve for the two following reasons.

1*st.* If the earth be undergoing a cooling process, it must at present contain an excess of caloric beyond what its affinity for it can retain. Now, whence did it derive this excess of caloric? How could its central portions concentrate more heat in some former age, than they can afterwards retain? The notion that the earth contains more caloric at present, than its attraction or affinity for it can retain, implies, that it must have had a stronger affinity for caloric at some former period, than it now possesses. But then the query is, how could it lose its affinity for caloric, consistently with the principle, that the attractive and repulsive properties of matter are permanently inherent in, and inseparable from, the matter itself? Possibly it may be imagined that the earth has formerly been a portion of the sun, and that it has been projected from its surface. If it be admitted that the sun is warmer than the earth, in consequence of the greater accumulation of ponderable matter, and the greater condensation of its central portions, it may be supposed, that a portion of matter of the bulk of the earth projected from its surface, might long afterwards contain a greater amount of caloric, than its own individual attraction for it can continue to retain. But then comes the query; how has the earth been projected from the sun? Where is the evidence for such a supposition? The impossibility of giving any thing approaching to plausible answers to these queries, leads me to think that the globe is undergoing no cooling process; and that the observed increment of temperature, at the mean rate of one degree for every 50 feet of perpendicular descent, below the surface of the ground, to all attainable depths, constitutes the equilibrium of heat in the earth; just as the increment of one degree for every 300 feet of descent in the atmosphere, constitutes the equilibrium of heat in that comparatively rare medium.

2d. It has been ascertained that the facility with which different substances conduct caloric, has a general, though not a perfectly strict, relation to their density. Thus, the metals, which, considered as a class, are the densest substances, are also the best conductors of caloric, though their conducting power is not strictly in the order of their density. For instance, silver and copper, though less dense, are considerably better conductors of caloric than platinum or lead. After the metals, stones, a less dense class of bodies, are the most rapid conductors; those which are densest and least porous being generally the best. But the fact of importance in the present inquiry is, that metals, and all other substances, have their powers of conducting caloric increased by condensation, by whatever means effected. Thus, a heated body will cool faster, if surrounded by a given thickness of any metal, or any non-metallic solid, provided that solid be previously condensed, such as may be effected by hammering, or any other artificial compression, than it will do, if surrounded by the same thickness, of the same substance, uncondensed by artificial compression.

It has been already stated, that, in descending from the surface towards the centre of the earth, the successive strata of terrestrial materials must increase in density, in consequence of the gradual increase in the superincumbent weight of the external strata of ponderable materials. Now, as the facility with which all bodies conduct caloric is increased by condensation, by whatever means effected, the conducting power of terrestrial materials, or in other words, the rapidity with which dispersing caloric passes through a given thickness of them, must increase with their condensation, from the surface to the centre of the earth.

Suppose we start at the depth of 40 feet below the surface of the ground, where the temperature remains unaltered throughout the year. As the first 50 feet of farther descent must, in general, be less dense than the second; and the second less dense than the third; and the third less dense than the fourth; and so on; it follows, that if any central accumulation of caloric be slowly penetrating the crust of the earth, and escaping from its surface by radiation, that the fourth fifty feet from the surface, must be receiving heat by conduction from the fifty feet of earth below it, more rapidly than it is communicating heat to the fifty feet above it. In like manner, the third fifty feet from the surface must be receiving heat from the fifty feet of earth underneath, more rapidly than it is communicating heat to the fifty feet of earth above; and so on. Hence, it is evident, from this law of conduction, that, if central heat were penetrating towards the surface of the earth, the successive strata near the surface would rapidly assimilate in temperature; those above becoming as warm as those underneath. Now, according to M. Arago, the mean temperature of the earth's surface cannot have varied so much as one-fifth of a degree, (and there is no evidence of its having varied at all,) during the last two thousand years. But if central heat has been penetrating towards, and escaping by radiation from, the earth's surface during all that time, the temperature of the different terrestrial strata within reach of observation, must have long since been assimilated; and provided the equilibrium of heat, and equality of temperature, in descending towards the earth's centre, were synonymous terms, as geologists seem to imagine; it is absurd to suppose that a difference of temperature, amounting to twenty degrees of Fahrenheit, between the warmth at the earth's surface, and that of strata at the depth of 1000 feet, could have now existed.

We come now to the explanation of the phenomenon, which, in the preceding pages, has been repeatedly hinted at. If the foregoing arguments be sufficient to prove, contrary to the almost universally received opinion of geologists, that central heat is neither penetrating towards, nor escaping by radiation from, the earth's surface. And, judging from the information communicated by geological researches, if we recollect, that the earth must have lasted, not for thousands, but for millions of years; and that caloric, from being able to pervade all ponderable materials, must have been tending, during the whole of that lengthened period, to distribute itself in the different concentric layers of the earth, in quantities everywhere proportioned to the conjoint influence of all the forces which act upon it. And if we at the same time admit, in accordance with the evidence adduced, that the temperature of the earth actually does increase, at the mean rate of one degree of Fahrenheit for every 50 feet of perpendicular descent; we have no alternative but to believe, that this rate of increment in descending constitutes the equilibrium of heat. This, therefore, is the distribution, which caloric, in obedience to the conjoint influence of the forces by which it is actuated, naturally adopts in the successive layers of ponderable matter, more and more condensed by the increasing weight of superincumbent strata, as we descend from the surface towards the earth's centre. And this is the distribution that caloric, so long as undisturbed by adventitious causes, permanently maintains; and which, if disturbed at any time by adventitious causes, such as the percolation of water, it has always a tendency to recover and resume.

The farther explanation of the nature and cause of the increase in the temperature of the earth, upon descending perpendicularly, which we have now to propose, is perfectly analogous to that given in the previous Section, of the decrease in the temperature of the air on ascending perpendicularly. The first and primary agent which contributes towards the effect, is the incumbent weight of each

50 feet of earth as we descend, in compressing the strata interior to them. This incumbent pressure diminishes the specific heat of all terrestrial materials lying underneath, and converts a portion of what would otherwise be latent into sensible heat; or in other words, it increases their temperature in proportion, or nearly in proportion, as it diminishes their specific heat. And the circumstance why that latent heat, when converted into sensible heat, has no tendency to escape outwards, so long as the rate of increment in descending does not exceed the mean of one degree for every 50 feet, I conceive is owing to the repulsion exerted upon interior caloric, by that which is exterior to it. The repulsion of external towards internal caloric, appears to have a compressing influence, somewhat analogous to that of the incumbent weight of external strata of ponderable materials, upon those that are interior to them. The deeper we dig into the earth, the greater is the amount of external caloric repelling that which is within; and, consequently, the greater is the calorific compression exerted from without, towards that which is interior.

In all cases of artificial condensation of terrestrial materials, the cause of condensation produces no corresponding increase of calorific repulsion, above and around the substance condensed. Hence, when any body is artificially condensed, its latent heat, upon being converted into sensible heat, escapes by dispersion, and is never retained by the body condensed. On the contrary, when condensation, as we dig deeper into the earth, is occasioned by an increased incumbent weight of ponderable matter, the cause of condensation is always accompanied with an increase of incumbent caloric, which, by repelling caloric that is interior to it, has the effect of retaining a portion of the latent heat converted into sensible heat, when the amount so converted does not elevate the temperature, on descending, above the rate of one degree for every 50 feet.

The preceding explanation of the rise in the temperature of the earth, on descending perpendicularly, is corroborated by the fact, that the rate of increment with the depth, is similar in all latitudes, and in all situations, whether low-lying or in an elevated country. It is the incumbent weight of the 50 feet of earth, which diminishes the specific heat of that which is immediately underneath. And it does not matter whether that 50 feet of earth be in the equatorial, the temperate, or the polar regions; or whether it be on a level with the sea, or at the altitude of 10,000 feet above it.

Thus we see, that the same law that applies to the atmosphere, which may be considered as the outer concentric layer of ponderable matter, is equally applicable to the more condensed strata of the subjacent earth. The chief difference is, that in the atmosphere, the temperature increases on descending, at the mean rate of one degree for every 300 feet; whereas, in the heavier and more condensed strata of the subjacent earth, the mean rate of increment, is one degree for every 50 feet of descent. And though inequality of temperature in the same concentric layer of earth, at the same depth below the surface of the ground, invariably causes caloric to move from where temperature is highest, to where it is lowest; still, such is not true in regard to the different concentric layers of earth, as we descend perpendicularly from the surface towards the centre of the globe. On the contrary, the circumstance of the increase upon descending being permanent, indicates that the equilibrium of heat below the surface of the ground occurs, when the temperature rises at the mean rate of one degree of Fahrenheit, for every 50 feet of perpendicular descent. And so long as this rate of increment upon descending is preserved, internal caloric must remain in a state of rest, as it can have no more tendency to penetrate towards the earth's surface, than it has to penetrate towards its centre. Hence we arrive at the ultimate conclusion, viz. that we are warranted in believing, that the temperature of the earth increases with the depth below the surface; but it is an error in geologists to suppose, on that account, that the globe is undergoing a gradual cooling process, in consequence of its central heat slowly penetrating its crust, and escaping by radiation for ever from its surface.

SECTION XXXVIII.

INQUIRY INTO THE RELATION SUBSISTING BETWEEN THE TEMPERATURE AND SPECIFIC HEAT OF THE DIFFERENT CONCENTRIC STRATA OF THE EARTH, AND THE ABSOLUTE AMOUNT OF CALORIC CONTAINED IN THEM.

Before proceeding with any farther examination of evidence either in favour, or in refutation, of the preceding views, it may be proper to inquire, how far the increase of temperature in descending towards the earth's centre, indicates a corresponding augmentation in the absolute amount of caloric in a given space. Admitting the increment of temperature to be one degree of Fahrenheit for every 50 feet of perpendicular descent; it follows, that for every mile of perpendicular descent, the temperature should increase 105·6 degrees. Now, the distance from the surface to the centre of the earth, in round numbers, is 4000 miles. Provided, therefore, the rate of increment continues the same from the surface to the centre; the temperature at the centre should be no less than 422,400 degrees of Fahrenheit warmer than at the surface. The temperature of bodies, and spaces, however, is determined, not by the absolute amount of caloric they contain, but by the amount they contain in relation to their specific heat. And the specific heat of bodies and spaces, is not a definite quantity, which remains unaltered in all situations and circumstances: for it diminishes as the incumbent pressure becomes greater. It is evident, therefore, that temperature, from its connexion with the specific heat of bodies, which, in descending towards the earth's centre, must in general diminish with the increase of the incumbent pressure, cannot give us a correct estimate of the absolute amount of caloric, contained in the different concentric strata of the earth.

By way of rendering this subject more intelligible, we will here venture upon giving a somewhat hypothetical explanation of the manner, in which we conceive the specific heat of bodies is diminished by condensation.

We have already repeatedly alluded to the caloric contained in the atmosphere being divided into two portions, one of which is held in affinity by the ponderable bases of the individual aerial particles; and the other is not so held in affinity, but exists intermediate between the aerial particles, or it may exist in a Torricellian vacuum, where there is no ponderable matter to retain it in attraction. The intermediate portion, we conceive, is retained in attraction around the globe, and partly intermixed with its superficial and less condensed strata, by the distant unsatisfied attraction for caloric of the central portions of the earth, which we supposed to be partly deprived of their due share of caloric by compression. If, for the sake of perspicuity, we consider these two portions separate, then the former is retained by the force of attraction subsisting between it and the ponderable particles, by which it is held in affinity; and the other portion, except for the distant unsatisfied attraction exerted towards it by the central portions of the earth, may be regarded as distributed by means of repulsion subsisting between its own particles.

Of these two portions of caloric, the former only admits of being condensed. If we condense any ponderable substance, such as air, we increase the number of its particles in a given space; and, according to the principle of forces being permanently inherent properties of matter, we proportionally increase the attraction exerted by ponderable matter upon caloric in that space. But this increased attractive force, can only augment the amount of caloric which is concentrated by the attraction of the ponderable particles subjected to condensation. The other portion of caloric, viz. that which is distributed by.means of repulsion subsisting between its own particles, has a relation to space. Its quantity, at any given temperature, is proportional to the amount of space, and cannot be condensed into smaller bounds, without producing an increase of temperature. Of course, if we condense a portion of air, or in other words, if we diminish the amount of space it occupies, a portion of this caloric contained therein must escape. Hence one reason, why increasing the density of air is accompanied by a partial evolution of caloric, and a diminished calorific capacity; and why diminishing its density is accompanied by a proportional absorption of caloric, and an increased calorific capacity. The preceding reason for the specific heat of bodies being diminished by condensation, is peculiarly applicable to gaseous substances, on account of their containing only a small amount of ponderable matter, relative to the space they occupy: what follows is more applicable to denser materials.

Another reason why condensation lessens the calorific capacity of ponderable matter, arises from its diminishing, in a greater proportion, the spaces throughout which the caloric contained in it is diffused, than it diminishes the whole space which the substance subjected to condensation occupies. The ponderable particles of any ponderable substance, may be conceived to be minute solid bodies, incapable of condensation, which occupy, according to the density of the substance, and to the exclusion of all other matter, a greater or less proportion of the space, which the aggregate body appears to fill. On the other hand, the calorific particles contained within any ponderable body, may be conceived to be diffused around its several ponderable particles, in the form of atmospheres. And the repulsion subsisting between these calorific atmospheres, is the cause which maintains a separation between the mutually attractive ponderable particles. Accordingly, all the vacuities within any ponderable substance, exist between the calorific particles diffused in the intermediate spaces between the ponderable particles; and the aggregate amount of these vacant spaces, compared with the aggregate bulk of the body, may be supposed to be smaller, in proportion as the density of the ponderable substance is greater. But vacuities only admit of the introduction of matter: spaces already filled with matter do not admit of the introduction of more. Accordingly, the condensation of any ponderable substance, consists merely in diminishing the vacuities between the particles of caloric that constitute the calorific atmospheres, which surround and separate the ponderable particles of which the ponderable substance is composed. Now, as these ponderable particles are incapable of being condensed, and accordingly, fill, to the exclusion of all other matter, a determinate proportion of the space which the aggregate body occupies; it necessarily follows, that condensation diminishes the intermediate spaces throughout which the caloric is diffused, in a greater proportion than it diminishes the aggregate space which the body subjected to condensation occupies.

Let us suppose, for the sake of illustration, that the ponderable matter in a given dense body fills one half the space which the body appears to occupy; and that caloric is diffused around its ponderable particles throughout the other half. If this body be condensed to three-fourths of its previous bulk, it is evident, that as the ponderable particles individually are incapable of condensation, the aggregate amount of the intermediate spaces throughout which the caloric is diffused, must be diminished one-half, while the bulk of the whole body is diminished only one-fourth. In short, the distance from the surface to the centre of the ponderable particles individually, suffers no diminution during condensation; while the intermediate vacuities between the calorific particles, distributed around the several ponderable particles in the form of atmospheres, undergo the whole diminution. And as repulsive and attractive forces, subsisting between particles of matter, increase as the square of the distances between them diminishes; it is obvious that condensation of any ponderable body, should augment the repulsion subsisting between the particles of caloric contained in it, in a more rapid ratio, than the attraction exerted by the ponderable matter upon the caloric it contains is increased. And hence another reason why condensation diminishes the specific heat of bodies. Bearing these observations in mind, let us next inquire into the earth's density, so far as has been ascertained.

Dr. Maskelyne, with a view to determine the mean density of the earth, according to the Newtonian principle, of every portion of matter attracting, and being attracted by, every other, with a force proportional to their respective amounts, and inversely as the squares of the distances between them, ascertained, that the attractive force of Shehallien, a mountain in Scotland, caused a plumb-line suspended about half-way up the mountain, to deviate from its perpendicular position, to the extent of 5″·8. The mean specific gravity of the materials composing the mountain, according to the estimate corrected by Professor Playfair, was 2·716, water being 1·. From these data, conjoined with the dimensions and form of the mountain, considered in relation to the positions on its opposite sides where the observations were made, the mean density of the earth was estimated at 4·867.

According to the experiments of Mr. Cavendish upon the attraction of leaden balls, made with the same intention as the observations of Dr. Maskelyne, but conducted upon principles less liable to error, in so far as the form, dimensions, and specific gravity, of the materials employed, could be more accurately determined than those of the mountain; the mean density of the earth is 5·48, water being 1·.

Now, the only cause for an increase in the absolute amount of caloric, in a given space, on descending towards the earth's centre, is the augmentation, in a given space, of the amount of ponderable matter which attracts caloric. Supposing, therefore, that none of the caloric is expelled by condensation, the increase in the absolute amount of caloric contained in a given space from the surface to the earth's centre, cannot be greater than the augmentation in the amount of ponderable matter. But taking the estimate of Mr. Cavendish, the mean density of the earth is only 5·48, which is little more than twice the mean density of the terrestrial materials around us, on the surface of the ground. The mean absolute amount of caloric contained in a given space within the earth's surface, can, therefore, be little more than twice what it is at its surface. Now, if we recollect, that ponderable matter is incapable of being condensed, and that only the vacuities subsisting between the ponderable particles throughout which caloric is diffused, admit of condensation, though we were to take the density of the earth at its centre at five times its mean density, which is probably greatly beyond the truth, the density at its centre would merely be 27·40, that of water being 1·.

Now, taking the mean density of the terrestrial materials at the earth's surface at 2·5, and supposing that the absolute amount of caloric, in a given space, increased from the surface to the earth's centre, in exactly the same proportion as the amount of ponderable matter, (though, for reasons already stated, it probably increases in a less ratio,) the absolute amount of caloric contained in a given space at the earth's centre, could not be above 11 times greater than at its surface. But by the estimate of temperature increasing at the mean rate of one degree for every 50 feet of perpendicular descent, we have seen that the temperature at the centre of the earth, should be no less than 422·400 degrees of Fahrenheit warmer, than at its surface. The reason of this apparent discrepancy is, that the absolute amount of caloric contained in a given space, in the different concentric layers of the earth, in descending towards its centre, cannot increase in any greater proportion than the amount of ponderable matter which attracts it. Whereas, the specific heat of each concentric stratum diminishes, and, provided all the caloric be retained, its temperature rises, in exact proportion as the force by which it is compressed; and therefore, in exact proportion as the incumbent weight of ponderable materials gravitating towards the earth's centre, is augmented. Hence, the tendency of caloric to escape from the earth into any body transferred to a depth below the surface of the ground, and protected from the incumbent pressure, such as mercury in a thermometer, must be proportional to the diminution of specific heat of the terrestrial materials, arising from the incumbent pressure of earth at that depth. And in a mine, the tendency of caloric to pass from the surrounding earth into the air, or into a pool of water, at its bottom, must be proportional to the difference in the diminution of the specific heat of earth and air, arising from the difference of pressure exerted by the incumbent earth surrounding the shaft of the mine, and by the incumbent air in the shaft, at the depth where the observations are made. And the equilibrium of caloric in the air, and in the surrounding earth, at the bottom of the mine, can only be established, when they exhibit an equality of temperature.

SECTION XXXIX.

ON THE CAUSE OF HOT SPRINGS.

THE explanatory hypothesis advanced in Section XXXVII., receives some confirmation from the satisfactory manner in which it accounts for hot springs, that are of such frequent occurrence in different parts of the earth's surface. Upon this point, Dr. Thomson, in his recent work on Geology, page 25, when reasoning on the supposition, of the observed increment of temperature, on descending below the surface of the ground, being true, though he subsequently endeavours to refute this doctrine altogether, says: "The temperature of a spring must depend upon the depth from which it rises. Were a spring to rise from the bottom of Dolcoath mine, which is 1,381 feet deep, to the surface, its temperature would be 84°, or 33° higher than the mean temperature of the place. Now, this happens to be the temperature of Buxton hot well, in Derbyshire. We have only to suppose, that the water fills a cavity 1,381 feet below the surface, and that from this cavity it rises in a natural pipe to the surface, to be able to account for the temperature.

"The temperature of the hottest of the Bath springs is 117°, while that of the air is 50°; so that the Bath spring is 67° higher than the mean heat of the place. If we allow an increase of 1° for every 50 feet of descent, it is obvious that Bath water must form an accumulation in a cavity situated 3350 feet below the surface of the earth. This amounts to 558 fathoms, which is much deeper than any mine, at least in Great Britain."

I am aware that the warmth exhibited by the water of hot springs, has been ascribed to other causes, than the one above-mentioned. By some, it has been attributed to the oxydizement of mineral substances in the earth, through which the waters of the spring percolate. By others, it has been ascribed to the waters of the springs coming into contact, in subterranean passages, with volcanic rocks raised to within a limited distance of the surface of the earth, and which still retain a portion of the heat they possessed, at the time they were ejected in the fluid form of lava. Both these hypotheses are proven to be erroneous, by the fact of hot springs continuing for ages to exhibit the same unvarying temperature. At the meeting of the British Association, held at Bristol, in 1836, Professor Forbes stated that he had recently ascertained the temperature of a hot spring in the Pyrenees, the warmth of which had been examined, and recorded, by different persons, at various intervals, for upwards of a century past. From comparing its temperature at the time of his visit, with its warmth as recorded by previous visitors, it appeared that the temperature of this hot spring had undergone no sensible alteration during the whole of the above-stated lengthened period. A similar observation, I believe, is applicable to the hot spring at Bath, as well as to those in most other quarters.

Now, this unvarying permanence in the temperature of hot springs proves, that the warmth which they exhibit, cannot be owing to the oxydizement of mineral substances getting into contact with air or water: for gradually as the mineral substances got oxydized, this source of heat would diminish. In like manner, the warmth exhibited by hot springs, if derived from volcanic rocks thrown up, in a state of fusion, to within a limited distance of the surface of the earth, could not continue permanent. Gradually as the water abstracted heat from such rocks, so would this source of warmth diminish. Consequently, hot springs which thence derived their heat, instead of continuing to maintain a uniform degree of warmth for ages, should be gradually undergoing a reduction of temperature. Not so, however, with hot springs deriving their heat from percolating, for considerable distances, through terrestrial strata, at such a depth below the surface, as is required to account for the warmth of the water of the spring, when it reaches the surface. Whatever heat the water may carry off from these terrestrial strata, may be conceived to be replaced by the tendency of caloric to re-establish that distribution in which its equilibrium consists. Besides, this latter mode of accounting for the phenomenon is rendered more probable, by the fact of hot springs seldom, or never, making their appearance at the surface of the earth, except where comparatively elevated lands are in the immediate neighbourhood, and under which, in deep subterranean channels, the water of such springs may be supposed to have percolated, and acquired its warmth. Such is the case with the hot springs of Bath and Buxton. Comparatively high lands are in the immediate neighbourhood of the springs, under which, in deep subterranean fissures, the water may be supposed to have acquired its high temperature. And the circumstance of hot springs being more frequently found in the neighbourhood of certain rocks, or at the junctions of certain rocks, than in other quarters, may depend upon the fissures of such rocks affording facilities to water to percolate to great depths, and to great distances, in subterranean channels, before appearing at the surface.

Upon this point we will only farther remark, that where hot springs make their appearance in the immediate neighbourhood of active volcanoes, the warmth of the water may no doubt be owing to communication with heated materials, ejected, to within a limited distance of the surface of the earth, by volcanic agency. But in all cases where hot springs make their appearance in places remote from any volcano; and where no volcanic agency has existed within the period of recorded history; provided the temperature of the springs continues permanently without variation, it is reasonable to suppose, that the heat of the waters is derived from the constant high temperature of the deep subterranean channels, through which they have percolated.

SECTION XL.

OBJECTIONS TO THE NEW VIEWS, ADVANCED IN SECTION XXXVII., REGARDING THE NATURE AND CAUSE OF THE INCREASE OF TEMPERATURE, ON DESCENDING PERPENDICULARLY INTO THE EARTH, ANTICIPATED AND ANSWERED.

THE objections which have been urged against the commonly received opinions regarding the nature of central heat, are principally intended to demonstrate, that there is some fallacy, or oversight, in the recorded observations on that subject; and that in reality there is no such thing, apart from temporary and accidental causes, as any rise in the temperature of the earth, on descending perpendicularly. As the fact of the increase in the earth's temperature on descending perpendicularly, has been admitted in the new views advanced on this subject in Section XXXVII., though explained in a different manner from what has been hitherto done, the objections urged against the commonly received opinions regarding central heat, are, for the most part, equally applicable to those we have advanced. We shall, therefore, proceed to examine them as they suggest themselves.

1*st*. If the increasing temperature of the earth upon descending perpendicularly, results from a portion of caloric becoming sensible, in consequence of compression, which would otherwise be latent; it might be anticipated, that a similar law should hold good in the temperature of the water of the ocean, and in that of deep lakes. This, however, is not the case. On the contrary, from all the observations that have been made, at least within the torrid zone, and in all temperate latitudes, the temperature of water, upon descending perpendicularly, instead of increasing, like that of land, actually diminishes. The observations show, that the oscillations in the temperature of the ocean, and also of deep lakes, above and below the mean for the latitude, are restricted, in a great measure, to the surface. Below the depth of forty fathoms, the annual variations of temperature are not perceptible. In fresh water, when the temperature at the surface is above 40°, the temperature sinks as the depth becomes greater, until it reaches that point, when it remains stationary; and gradually, as it approaches that point, the decrements of temperature for equal increments of depth, become less. On the contrary, when the temperature of the surface is below 40°, the temperature increases with the depth, till it reaches that point, and at all farther depths remains stationary.

The following Table, giving the temperature of the Swiss lakes, as determined by De Saussure, together with the subjoined quotation, is extracted from an article in Vol. XXIII. of the 'Edinburgh New Philosophical Journal':—

Places.	Temperature of the Water:		Depth in Feet.	Dates of Observations.
	on the Surface.	at the Bottom.		
Lake of Geneva,	42°·09	41°·74	950	1777, Feb. 6.
Do. do.	70°·13	43°·09	150	1775, Aug. 5.
Lake of Thun,	65°·5	41°·00	350	1783, July 7.
Lake of Brienz,	66°·24	40°·69	500	1783, July 8.
Lake of Lucerne,	68°·49	40°·74	600	1783, July 28.
Lake of Boden,	63°·59	40°·00	370	1784, July 25.
Lago Maggiore,	77°·00	44°·03	335	1783, July 19.
Lake of Neufchatel,	73°·59	41°·00	325	1779, July 17.
Lake of Biel,	69°·23	44°·34	217	1779, July 20.
Lake of Annecy,	57°·84	42°·09	163	1780, May 14.
Lake of the Bourget,	63°·24	42°·09	240	1781, Oct. 6.

"According to De la Beche's observations on the Lake of Geneva, the temperature of the water, at depths of forty to seventy fathoms, seems everywhere to be 43°·9, except only at Ouchy; and from eighty fathoms downwards to the greatest depths, he found a constant temperature of 43°·04. In lesser depths than forty fathoms, the temperature varies according to circumstances, but to that limit it always decreases from the surface downwards. In the Lake of Thun, De la Beche found the temperature at the surface to be 59°·9, whilst at a depth of 105 fathoms, it was 41°·4; and in the Lake of Zug, the temperature on the surface was 58°·, whilst at a depth of thirty-eight fathoms, it was 41°·. Three to four hundred fathoms deep, in the Lago di Como, Volta found a temperature of 43°·2.

On the 16th April, 1798, Von Humboldt found the temperature of the water of the Lake of Barthomew, in the Berchtesgaden Alps, at a depth of 2 feet, to be 45°·83; at 42 feet, 43°·13; at 60 feet, 41°·; and at another spot, at a depth of 84 feet, 42°·09. Recent measurements of D'Urville, and of Boubee, in the Lake of Oo, near Bagneres de la Chou, have given the same results.

"Thus we find, that the temperature in the depths of lakes approaches that of fresh water at its greatest density, which, according to the latest accurate experiments of Stampfer, is 38°·75."

The facts above quoted, as well as all similar ones, have been explained by referring to the mobility of water, in connection with the statical law, of its particles becoming heavier with increase of coldness, till they reach their maximum density of 38¾°·. Hence, all the cold impressions communicated to the surface during night or winter, so long as the temperature remains above 38¾°·, are transmitted downwards by the sinking of the cold particles, while the warm impressions remain chiefly on the surface, till dissipated by evaporation, radiation, or aerial convection.

The objection presented by the facts quoted to the commonly received opinions regarding the central heat of the earth, has been supposed to be obviated by the circumstance, that in none of the many observations which have been made, has the minimum temperature, obtained at great depths in fresh water lakes, ever been so low as the point at which fresh water attains its greatest density. It has always been somewhat above it—the amount varying in different experiments from 1·35 to 5·74 degrees.* Provided there was no cause to prevent the temperature sinking at great depths, to the point where water attains its maximum density, it is evident, that during the continued cold of winter, and long before any portion of the surface could freeze, the whole water from the surface to the bottom must reach the temperature of 38·75. But the fact of its never reaching that point at great depths, indicates, that there is some counteractive cause. Now, what is that cause? The advocates for the dissipation of the central heat of the earth say, that it is the gradual penetration of this heat, and communication of it to the water at the bottom of the lakes. If we admit that central heat is continually penetrating the crust of the earth, and escaping by radiation from its surface, this explanation would be sufficient to explain the phenomenon. But various reasons have been already stated for thinking, that there is no outward penetration, nor escape of central heat.

The only other way to account for the fact, is to suppose that the specific heat of the water, and probably also of the earth at the bottom, is diminished by the incumbent pressure; and that a portion of it is converted into sensible heat, and retained in the same manner, as we accounted for the detention of the latent heat converted into sensible heat, in descending through the atmosphere, and likewise from the surface of the ground downwards.

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* Similar remarks are said to be applicable to the waters of the ocean, the observations in which we omit inserting, because the point of maximum density cannot be so well ascertained, in consequence of its varying with the amount of salt held in solution.

It may be objected to the preceding explanation, that if it were true, the temperature of water at equal depths ought to be alike, and after reaching a minimum, should increase uniformly with the depth; whereas, judging from the recorded observations, there is no evidence that such is the fact.

In answer to this objection it may be stated, that to enable us to form a correct opinion on this point, we would require to know the influence of compression in diminishing the specific heat of water, a circumstance with which I am totally unacquainted. Judging, however, from the fact, of water being composed of the strongest electro-positive and negative elements known; and consequently being condensed, and having its specific heat diminished, by the strongest chemical affinity known; it is probable, that its specific heat is extremely unsusceptible of being diminished by incumbent pressure. And, except for the air contained in water, which must be expelled by the incumbent pressure at great depths, it is also probable, for the reason above stated, that it is extremely incompressible. Now, if the preceding supposition be true, the temperature of water at great depths, owing to the extreme unsusceptibility of its specific heat undergoing diminution with incumbent pressure, may be augmented in only a very slight degree thereby. And the principal part of the increase in the temperature of the water at great depths, above the point where it attains its maximum density, may be owing to the greater susceptibility of the specific heat of the earth at the bottom, to be reduced by incumbent pressure. Of course, if this be the case, the earth at the bottom of lakes will be slowly communicating warmth to the incumbent water, derived from underneath by conduction. And this supply of heat which the water receives, will be rapidly transmitted upwards to the surface almost without loss, in consequence of the inferiority of water as a conductor of caloric, conjoined with its remarkable mobility, and power of carrying it. Hence, the circumstance of the temperature of water at the bottom of lakes, never having been found so low as the point at which water attains its greatest density, may be partly owing to a slight diminution in its specific heat, arising from incumbent pressure, and to a retention of latent heat, converted into sensible heat, upon the same principle as the retention of the latent heat of the air and of the earth, when converted into sensible heat by incumbent compression, was explained. The circumstance under consideration may also be partly owing to the supply of caloric, which the water constantly receives from the earth at the bottom, with different degrees of rapidity in different lakes, according to their depth, and the fitness of the earthy materials underneath for conducting caloric.

2*d*. Another objection urged in opposition to the hypothesis, that the temperature of the earth increases with the depth below the surface, is, that the increment is only observable in mines when they are working. Upon this point Dr. Thomson makes the following remarks:—*

"The observations of Mr. Moyle, which were made during a series of years in Cornwall, seem to show that the high temperature of the mines in that county continues only while they are working. When these mines are abandoned, they get filled with water, which, of course, remains stagnant, and the temperature gradually sinks till it approaches that of the mean temperature of the place. The Oatfield engine shaft, at a depth of 182 fathoms, had a temperature of 77° while the mine was working. Mr. Moyle examined the temperature at that depth a few months after the mine had been abandoned, and found it reduced to 66°. He tried it again many months after, and found the temperature reduced to 54°. Thus, the temperature at the bottom of this mine had sunk, after it was abandoned, no less than 23°. It is obvious, that if the original high temperature had been derived from the central fire, the mere abandonment of the mine could not have reduced it.

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* Outlines of Mineralogy, Geology, and Mineral Analysis, vol. II. page 26.

" Mr. Moyle found the temperature in the abandoned mines of Herland and Huel Alfred, that of the former 54°, and of the latter 56°, and this at all depths. The working of these two mines being resumed, the water was drawn off, and Mr. Moyle examined it, during the operation, to the depth of 100 fathoms without finding any increase of temperature.

" Huel Trenoweth is another example, which Mr. Moyle has brought forward. It is 100 fathoms east of Crenver and Oatfield mines, in the same *load.* This mine was discontinued working for more than twelve months, at least as far as regards the presence of miners; but the engine was still kept working, to relieve the other two mines. The adit at which the water is discharged, is 32 fathoms from the surface. Here its temperature was 54°; and it gradually increased from this place to the mouth of the pump, where it was 56°. Fifteen fathoms deeper, the walls of the shaft were 54°. A gallery at this level, 40 fathoms east of the shaft, was only 53°. Five fathoms deeper, or 52 from the surface, where there is a second cistern of water, the water was 57°; the walls in the same place were 54½°. At the bottom, in 66 fathoms, the water that ran through a small crevice, as well as the walls of the shaft, were still 54°. The temperature of the air before going down was 68°, after returning 64°. Here it is obvious that there was no increase of temperature for 34 fathoms, being precisely the same at the bottom as at the adit shaft.

"These facts seem to me to leave no doubt, that the increase of temperature observed in mines as we descend, cannot be owing to the heat communicated from the central parts of the earth; for, if it were so derived, it could not disappear when the workmen left it, or when stagnant water was allowed to accumulate in it.

"If it were merely the air in the mine, or even the surface of its walls, which augmented in temperature, there would be little difficulty in accounting for the phenomenon. The number of miners usually present in the mine at one time, (often amounting to 400,) together with the heat from the candles, and gunpowder exploded, might easily be supposed to increase the temperature very considerably, and this temperature would naturally increase somewhat as the mine deepened, in consequence of the greater density of the air; but we have seen that these causes are utterly inadequate to account for the augmented temperature of the vast quantity of water which is daily pumped out of these mines.

"But to whatever cause we are to ascribe this augmented temperature, the facts above stated are incompatible with the notion that it is owing to a central fire."

Though the facts stated in the preceding quotation, as well as others of the same kind given in a tabular form, which we have not quoted, prove, that the increment of temperature observed in mines on descending, is greatest in, and even principally restricted to, mines in which the ordinary operations of mining are going on; still, they do not by any means invalidate the doctrine, that the temperature of the earth actually increases on descending perpendicularly. Suppose an abandoned mine gets filled with stagnant water to its mouth, provided that water receives no heat from the earth by which it is surrounded, its temperature should decrease with the depth, till it reached the point at which water acquires its greatest density, viz. 38·75 degrees; just upon the same principle, as the temperature of the water of deep lakes, sinks with the depth till it approaches that point. Now, the lowest temperature observed by Mr. Moyle, in abandoned mines, was 51 degrees, which is about the mean for the latitude; and that temperature was only observed at the very inconsiderable depth of from 150 to 200 feet.

Again, suppose an abandoned mine remains entirely free of water, provided the air within it receives no heat from the surrounding earth, its temperature (except for the one degree for every 300 feet of perpendicular descent) ought to sink as low, or nearly as low, as that of the air at the mouth of the mine during the coldest night of winter. The reason why this should be the case, is analogous to that which has been assigned for the coldness near the bottom of deep lakes. During night and winter, the cold air at the mouth of the mine, from its superior specific gravity, sinks down to the bottom. But during day and summer, the warm air at the mouth of the mine, owing to its inferior specific gravity, has no tendency to sink down and displace the cold air below. Hence the reason, that in caverns of very moderate depth, provided their mouths be sheltered from the rays of the sun, the temperature of the air near the bottom, is usually found to be much lower than the mean for the latitude. Now, the fact of Mr. Moyle never having observed a lower temperature in abandoned mines than 51 degrees, which is about the mean for the latitude, and that only at the inconsiderable depth of 150 to 200 feet, indicates that the temperature of the air in abandoned mines, is supported by heat derived from the surrounding earth.

But, then, it may be asked, how does the temperature of mines sink when they cease to work them? I answer, because the temperature of the earth, at a depth below the surface of the ground, is more freely communicated to the air within mines, when the mining operations are going on, than when they have ceased; and this effect is exclusive of adventitious causes of heat, such as miners' lamps, &c. which must likewise have some influence in raising the internal temperature of mines that are working. When a mine is kept free of water, by pumping, as in the case of Dolcoath mine, noticed in Section XXXVII., the heated water which finds its way into the mine, is constantly communicating warmth thereto, which it had acquired in percolating through the subjacent terrestrial strata, probably for a great distance around. But when such a mine is abandoned, and gets filled with stagnant water, this source of heat ceases, because the water collected in the mine acts as a counterpoise, agreeably to hydrostatic principles, in preventing all farther entrance of water from the surrounding earth. Consequently, the stagnant water in the mine, except for the supply of heat which it slowly receives by conduction from the surrounding earth, becomes thereafter subject to the same cooling influence towards the bottom, as the water in deep lakes, which we have already noticed.

Again, suppose an abandoned mine remains entirely free of water, provided the temperature at any considerable depth be warmer than that of the atmosphere at its mouth, heat must be rapidly abstracted from the mine by the power of the air in carrying caloric. A current of heated air close to the comparatively warm walls of the shaft of the mine, will be constantly passing upwards; while its place will be supplied by a current of cold air passing down the middle of the shaft. But supposing the temperature within an abandoned mine reduced to the mean for the latitude, provided the air within the mine was not receiving heat from the surrounding earth, reduction of temperature ought not to stop at this point, for the reasons mentioned in the last paragraph but one, and which need not be repeated. In this country, the temperature of the air at the surface of grass, during clear calm weather, sinks at night, even during the hottest period of summer, as low, and generally lower, than the mean for the latitude. And as the temperature of air in abandoned mines has never been observed below the mean for the latitude, and seldom so low, it may be concluded, that the surrounding earth must be supplying heat to the air in all abandoned mines.

Finally, if we recollect the extreme slowness with which heat passes through earth by conduction, as demonstrated by the observations of Mr. Ferguson of Raith, noticed at the beginning of Section XXXVII., and to which the reader is referred; it is easy to perceive another reason why the temperature of mines, in which mining operations are going on, should be higher than in those that have been abandoned. The power of the air in carrying caloric, agreeably to principles stated in the preceding paragraph, may account, for some time after a mine is abandoned, for the more rapid abstraction of heat from the walls of its shaft and galleries, than it is supplied thereto, from the surrounding earth, by the very slow process of conduction. When a mine is working, fresh uncooled portions of earth are constantly, and successively, brought into communication with the internal air; and they consequently impart a temperature to it, similar to that of earth, at a corresponding depth below the surface of the ground, where there is no mine. On the contrary, when a mine is abandoned, the layers of earth near, or in immediate contact with, the air in the shaft or internal passages of the mine, get slowly reduced in temperature, by the power of the air in carrying caloric. Gradually, however, as the temperature of the air within the mine gets reduced, its power of abstracting caloric therefrom by convection, diminishes. And the temperature ultimately becomes stationary, at the point where the supply of heat from the earth, slowly communicated by conduction to the air in the mine, balances the abstraction of heat, occasioned by the sinking down of the cold air at the mouth of the mine during night.

The preceding observations afford a sufficient explanation of the reason why the air in a mine that is working, should be warmer at great depths than in one that is abandoned, and that, too, independent of adventitious causes, such as miners' lamps, &c. Indeed, had the temperature of abandoned mines remained as high as when they were working, it would have been about as great a miracle, as though the temperature of an apartment in a dwelling-house during winter, should remain as high long after the fire had been nearly extinguished, as when it continued to burn with its greatest vigour. Upon the whole, when it is considered that water, upon finding its way into a mine, by percolating through the earth at great depths, is invariably heated; and, agreeably to the observations of Mr. Fox, stated in Section XXXVII., that a thermometer imbedded in the earth, in mines, always exhibits a higher temperature than one not imbedded; and when it is farther considered, that Mr. Moyle never observed a lower temperature in any abandoned mine than 51°, which is about the mean for the latitude, we must come to the conclusion, that Mr. Moyle's observations, even admitting them to be perfectly accurate, do not invalidate the doctrine, that the temperature of the earth increases upon descending perpendicularly.

3*d*. Besides the observations of Mr. Moyle, Dr. Thomson advances other arguments, which we will likewise here quote in his own language.

"It is sufficiently obvious, that the temperature of a place, *cæteris paribus*, is regulated by the latitude. The mean temperature of the equator is 81°·5; that of latitude 45°, is 56°; that of Stockholm, in N. latitude 60°, is 41°; and that of Lapland, in N. latitude 67°, is 32°. In the temperate and frigid zones, the mean temperature of summer is much higher than that of winter. This will be evident from the following table:—

Places.	Latitude.	Mean Winter Temperature.	Mean Summer Temperature.
Madeira, . .	32° 37′	63°·5	72°·28
Italy, . .	40° 50′	50°	77°
France, . .	43° 30′	44°·6	75°·2
France, .	47° 10′	41°·	68°
England, . .	53° 30′	37°·8	62°·6
Scotland, .	57°	36°·14	56°·48
Sweden, . .	60° 30′	24°·8	60°·8
Gulf of Bothnia,	62° 5′	16°·7	59°
Norway, . .	71°	23°·9	44°·7

" It is obvious from this Table, that in all these places the higher the sun is elevated above the horizon, and the longer it continues above the horizon, the higher is the temperature; and that in winter, when his altitude is low, and the days short, the temperature is much lower. From all this it cannot be doubted that the temperature is regulated entirely by the sun. Now, how could this be the case if there existed a central fire which makes its influence be felt so much as to raise the temperature 33° at a depth of 200 fathoms under the surface? It has been said, indeed, that the heat lost by radiation is just equal to that transmitted from the centre, so that the surface cannot be heated by the central fire, but only by the sun. But whatever effect may be ascribed to radiation, surely it must act equably on every part of the surface of the earth. But the poles are 12 miles nearer the centre than the equator is. Now, if every 50 feet of descent occasion an increase of 1°, 12 miles should occasion an increase of 1291°; so that allowing the heat dissipated from the surface by radiation to be equal at the poles and equator, still there ought to be an increase of more than 1200° of heat at the pole derived from the central fire; so that the temperature at the pole, instead of — 13°, ought to be enormously high. The low temperature of the pole, owing to the long absence of the sun, and probably also the absence of land, seems to me totally irreconcileable with the existence of a central fire in the globe, or at least with the notion that this central fire transmits heat to the surface in such quantity as to affect the thermometer."

It is obvious, that the objections urged in the preceding quotation, in opposition to the doctrine that the temperature of the earth increases at the mean rate of one degree of Fahrenheit, for every 50 feet of perpendicular descent, are only applicable to the hypothesis, which, on other grounds, we have also endeavoured to refute, viz. that the increase of temperature on descending, indicates that caloric is gradually forcing its way outwards. In opposition to such a hypothesis, the arguments above quoted have considerable weight, and do not admit of being satisfactorily answered. But in place of being opposed to the explanation we have given of the phenomenon, they rather tend to confirm it. The mean increment of temperature which the earth exhibits upon descending perpendicularly, constitutes, as we have endeavoured to prove, the equilibrium of heat; just upon the same principle, as the mean decrement of temperature which the atmosphere exhibits upon ascending perpendicularly, constitutes the equilibrium of heat, in that comparatively rare medium. The weight of 50 feet of earth must be very nearly as much at the equator, as at the poles. And according to our explanation of the phenomenon we have been considering, it matters not, except in so far as the weight of 50 feet of earth would be affected, whether the surface of the globe at the pole be

12 miles, or 1200 miles, nearer its centre than it is at the equator.

4th. Again, it may be objected to the explanation given in Section XXXVII., of the increase of temperature on descending perpendicularly into the earth, that if it were correct, the ratio in which the temperature increases with the depth, should be more uniform in different places, than it appears to be from the abstract previously quoted.

In answering this objection, it is necessary again to refer to the very slow manner, in which caloric passes by conduction through earthy materials; and also to the various ways, in which different increasing ratios of temperature might be produced, in different places. From the observations of Mr. Ferguson of Raith, it appears, that a thermometer at the depth of one foot below the surface of the earth, reaches its maximum and minimum temperatures, about three weeks after the summer and winter solstices: its extreme variation being 25°. Whereas a thermometer, at the depth of four feet, did not reach its maximum and minimum temperatures, till nearly two months after the solstices: its annual range being only 15°.

Now, if the slowness with which caloric penetrates the earth by conduction, as indicated by the above facts, be considered; it is obvious, that though caloric within the earth's surface be ever tending to distribute itself agreeably to its equilibrium; still, that equilibrium will be liable to be more or less disturbed, and the ratio in which the temperature increases in digging down perpendicularly in different places, will be proportionally modified by a variety of circumstances. For instance, in places where water passes downwards to any considerable depth, the ratio in the increment of temperature will be affected, by the water communicating the coldness it had at the surface, to the subjacent strata. It may also be affected in a contrary manner, by the gradual rising up of water towards the surface, from heated subterranean channels, through which it had previously percolated. Even the very difference in the density and weight of terrestrial materials in different places, may of itself produce a difference in the degree of condensation, and of the increase of temperature of the concentric layers at similar depths. And we will only farther remark, that it should be recollected, that the observations quoted were made in mines, the temperature of which may be affected by the different degrees of rapidity with which the mining operations are conducted; also by the unequal quantities of water which intrude into them, after having percolated through subterranean channels; and likewise by the inequalities in the ventilation of different mines, and even of the same mine, at different seasons of the year. These reasons afford a sufficient explanation, of the differences in the rate at which the temperature on descending in different mines, has been observed to increase.

5th. The last objection to the views we have advanced relative to the nature and cause of the central heat of the earth, is, that there exists geological evidence, that the climate in the northern parts of Europe, Asia, and America, has been much warmer, in some former age, than it now is. And hence it may be inferred, that the increment of temperature in descending perpendicularly, is the indication of that gradual cooling process, which the earth has been long, and is still, undergoing.

In answering this objection, it may be remarked, that if the increment of temperature on descending into the earth, be considered evidence that central heat is still passing outwards by conduction, and that the globe continues to undergo a slow cooling process, it is obvious from the observations made by Humboldt on the temperature of mines in Mexico, and Peru, that it is cooling as fast in the equatorial regions as in higher latitudes; because the rate in which the temperature increases on descending, is as great in the former as in the latter. Consequently, the notion of the escape of central heat from the earth's surface in the equatorial regions, being replaced by the heating influence of the sun, must be erroneous. For unless the increment of temperature on descending constitutes the equilibrium of heat, equality of temperature in descending would soon exist at all depths, if the sun replaced, in the superficial strata of the earth, as much heat as made its escape by radiation.

The evidence in support of the geological hypothesis, that the climate in high northern latitudes has been much warmer in some former age than it now is, rests upon the circumstance of fossil remains of animals and vegetables, supposed capable of existing only in warm climates, having been frequently discovered in these regions, deeply imbedded in rocks and strata underneath the surface of the earth. These phenomena having relation to an age antecedent to historical records, and being somewhat different from what could occur, in corresponding latitudes, under the present state of things, explanations of them cannot be expected to be any thing else than vague conjectures. The most unobjectionable mode of accounting for them is that which Professor Lyell has adopted, viz. to endeavour to reconcile them with the operation of causes still in being. He conceives that land in high latitudes, particularly if elevated, such as exists in the northern parts of North America, contributes to lower the mean temperature of neighbouring countries; and that land in equatorial regions, such as Africa, raises the mean temperature of all surrounding countries. Hence he concludes, that whenever a greater extent of land is collected in the polar regions, the cold will augment; and the same result will be produced, when there shall be more sea between and near the tropics; and *vice versa*. According to this principle he accounts for the greater warmth, in some former age, of the northern hemisphere, in the latitudes now occupied by Europe, Asia, and America, by supposing, that alterations in the proportions of land and water, in the equatorial and polar regions, must have taken place.

The preceding hypothesis, if tested by facts, is only partially true, and falls far short of explaining the phenomena. It must be admitted, that in all insular climates, the temperature is more uniform, and deviates less from the mean for the latitude, than in inland countries; and that the mean annual atmospheric temperature, to a limited extent, rises within, and sinks beyond, the 30th parallel of latitude, upon receding from the ocean. It may likewise be admitted, that an increase of land in the equatorial regions, would there increase the temperature, in proportion as it diminished evaporation, which in the lower strata of the atmosphere, where thermometric observations can only be made, is so great a cause of cold. But it is very questionable how far the mean temperature in high and temperate latitudes, would be reduced, by an increase of land in the polar regions, where all is ice and snow already. And the fact, (confirmed by the much farther extension of perpetual ice around the southern than the northern pole,) that the mean temperature is lower in the southern hemisphere, from the pole to about the 50th parallel of latitude, where there is no land, than what it is in the northern, where there is a great amount of land, refutes the Professor's conclusion.

If existing causes be insufficient to account for the warmth to which northern latitudes must have been subjected, in some former age, we have no other means of investigating the subject, but by forming conjectures as to what would have been calculated to have produced the effect. With such an imperfect guide to direct our inquiries, it need not be disguised, that instead of pretending to be able to advance an hypothesis that has the probability of being true, (for that is out of the question,) we should content ourselves with the most plausible of those that has the possibility of being true. Now, to account for the phenomenon under consideration by supposing, that caloric must have been accumulated and concentrated within the earth, in some former age, to an extent far beyond what it can now retain in affinity; and consequently, that the globe has long been, and still is, subjected to a gradual cooling process, is an hypothesis that cannot be admitted. If we believe that the attractive and repulsive properties of bodies, are inherent in, and inseparable from, the materials themselves; it follows, that the same repellent force subsisting between the particles of caloric, which could cause caloric to fly off from the earth at the present time, must have been sufficient in all former ages to prevent any greater accumulation of it within the earth, than what now exists. Hence, the explanation under consideration, from its requiring us to believe in an impossibility, is totally inadmissible.

Another common explanation of the greater warmth to which northern latitudes must have been subjected, in some former age, is, that the earth's axis has been changed; and we can easily perceive how such may have been occasioned. For instance, were a large comet, in its approach to, or recession from, the sun, to pass near the south or the north pole of the earth; by attracting the pole in the direction of its motion, it would unquestionably have some influence in altering the axis of the earth, and in fact would cause the earth thereafter to revolve round a new axis. Diluvial depositions, and the translation of boulder stones of granite to great distances from where similar rocks are to be found; likewise deeply imbedded subterranean forests, and vegetable remains, converted into coal formations, and the alternate layers of fresh and salt water sedimentary deposits, so frequently met with in geological researches, severally and conjointly indicate, that the course of rivers has been frequently altered, and that great tracts of land have been suddenly, and repeatedly, submerged, and again uplifted above the waters of the ocean. Now, no means has yet been thought of so well calculated to account for all these mysterious phenomena, as to suppose that the axis of the earth, in the course, not of thousands, but of millions of years, has undergone repeated alterations. On the other hand, there is no historical evidence that the axis either of the earth, or of any other planet, has ever been altered by the attraction of a comet; still, however, such a supposition, so far as we can at present judge, does not imply an impossibility.

We must here conclude this department of our subject by remarking, that the various objections which we have now examined, when fairly weighed and appreciated, do not appear to invalidate the evidence adduced in support of the hypothesis, that the temperature of the earth increases on descending perpendicularly, to all attainable depths, at the mean rate of one degree for every fifty feet. But as this increment of temperature on descending, according to our view of the matter, constitutes the equilibrium of heat, we believe that the notion at present almost universally received by geologists, that the earth has long been, and still is, undergoing a gradual cooling process, in consequence of central heat slowly penetrating its crust, and escaping by radiation for ever from its surface, is entirely erroneous; and instead of being supported, is actually contradicted, by every fact and argument entitled to the character of evidence.

THE END.

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